MODERN PROFESSIONAL NURSING

General Editor
MILDRED HAINSWORTH
R.R.C., D.N., S.R.N.

VOLUME ONE

THE CAXTON PUBLISHING CO. LTD.
MORLEY HALL, ST. GEORGE STREET, HANOVER SQUARE,
LONDON, W.1

First Published . . April 1922.
Reprinted . . . October 1949
Reprinted . . . June 1950
Reprinted . . . August 1951
Reprinted . . . May 1954
Reprinted . . . January 1956

PRINTED IN ENGLAND BY THE ALCUIN PRESS
WELWYN GARDEN CITY, HERTS

LIST OF CONTRIBUTORS

TO

MODERN PROFESSIONAL NURSING

(arranged alphabetically)

UNA W. DALDORPH, D.N., S.R.N., Sister Tutor Diploma (King's College Household and Social Science); Senior Sister Tutor, Royal Salop Infirmary, Shrewsbury; Examiner for the General Nursing Council for England and Wales,

FLORENCE DILLISTONE, S.R.N., R.S.C.N., S.C.M., Senior Dietician, The Hospital for Sick Children, Great Ormond Street, London. Formerly Ward and Departmental Sister, The London Hospital.

ANNE FORD, D.N., S.R.N., S.C.M., Registered Sister Tutor, Housekeeping Certificate, Tuberculosis Association Certificate; Sister Tutor, Royal Halifax Infirmary, Halifax; Examiner for the General Nursing Council for England and Wales.

MARY E. FORD, D.N., S.R.N., S.C.M., Sister Tutor's Certificate, King's College, London; Sister Tutor, County Hospital, Lincoln; Examiner for the General Nursing Council for England and Wales.

MILDRED HAINSWORTH, Sister Tutor, Queen Elizabeth Hospital for Children, Banstead, Surrey. (For further qualifications see title page.)

L. B. HENDERSON, D.N., S.R.N., S.C.M., Matron, Noble's Hospital, Douglas, I.O.M.

DOROTHY LEWIS, S.R.N., M.C.S.P., M.S.R., M.E., L.E.T. Formerly Sister in Charge, Physiotherapy Dept., The Hospital for Sick Children, Great Ormond Street, London.

ETHEL MURIEL LEWIS, S.R.N., R.S.C.N., S.C.M., Assistant Sister Tutor, The Hospital for Sick Children, Great Ormond Street, London.

ELIZABETH M. B. LOCKHART, S.R.N., R.S.C.N., S.C.M., H.V., Health Visitor, Stirling County Council; Formerly Medical Ward Sister, Royal Hospital for Sick Children, Glasgow, Sister Tutor, Greenock Royal Infirmary and Larkfield Hospital, Greenock, Lecturer to Civil Nursing Reserve.

G. O'GORMAN, M.R.C.S.Eng., M.R.C.P.Lond., D.P.M.Eng., Physician Superintendent, Borocourt Hospital, Peppard, Oxon.

PHYLLIS M. PIPER, D.N., S.R.N., S.C.M. Formerly Sister Tutor, Hove Hospital, Hove, Sussex. Examiner for the General Nursing Council for England and Wales.

H. B. C. SANDIFORD, M.R.C.S.Eng., L.R.C.P.Lond., D.A.Eng., F.F.A., R.C.S., Senior Anaesthetist, Portsmouth Hospital Group.

MILDRED MARY SLATER, S.R.N., S.C.M., Sister Tutor's Certificate, University of Manchester; Sister Tutor, North Lonsdale Hospital, Barrow-in-Furness; Examiner for the General Nursing Council for England and Wales

G. F. SOMERS, B.Sc., Ph.D., Ph.C., Lecturer in Pharmacology, School of Pharmacy, University of London.

HARRIETT WARD, D.N., S.R.N., S.C.M., Sister Tutor, Lewisham Hospital, London; Examiner for the General Nursing Council for England and Wales.

PREFACE

The first edition of Modern Professional Nursing had a wide circulation not only in Great Britain but in most parts of the British Empire. A second edition is long overdue, but the unavoidable delay in publication has given all concerned a better chance to make alterations and improvements; needless to say, full advantage has been taken of the opportunity thus provided.

Many nurses have been of the greatest help in making suggestions with regard to changes or additions; such healthy criticism is regarded by the Publishers as the life and soul of a work such as this is, and accordingly they have been very willing to accept many ideas put forward.

One radical change is noteworthy. Miss Mildred Hainsworth is now associated with this work as General Editor and she is ably supported by a group of sister tutors, specialist nurses and other experts from the ancillary branches of nursing—a very representative team indeed. Every line has been revised and the most careful scrutiny made of the facts presented, and therefore the Publishers are confident that the new edition will fulfil its mission: to bring to the student or graduate nurse all the information essential to a sound knowledge of nursing science and practice as it is established at the present time.

Believing as they do that a good illustration is a very important factor in education, the Publishers have made a special point of including pictures—in colour and in black and white—of the highest standard. The illustrations done by Miss Joan Fairfax Whiteside, R.R.C., speak for themselves; they play no small part in the work. It is believed that the clarity of the text will be still more greatly emphasized by the excellent coloured plates and line and wash drawings which have been added.

CONTENTS OF VOLUME I

SECTION I

ANATOMY AND PHYSIOLOGY

LIST OF PLATES

VOLUME I

COLOUR PLATES

little or no change for thousands of years. It is true that certain conditions of life have made local and trifling amendments to minute areas of the skin, of the organs, of the glands. The microscope has proved that certain elements in the composition of the body have undergone modification by a long process of gradual change. A different standard of living may have produced a slight deviation from the stock pattern of the Creation. But all these are as nothing when we regard the human being as a unit. Alive or dead we still preserve those definite and unmistakable characteristics which stamp us and which single us out as the predominant creatures of the animal kingdom.

The Body as a Whole

A general survey of the body shows that there are certain portions into which the mass is divided. For instance the head, the arms, the legs, the trunk, at once suggest themselves as simple and easily recognized divisions. In addition we may take note of parts in which there is apparently more bulk of flesh: examples of this are the calves of the legs, the buttocks, the shoulders and the breasts. Further observation confirms that if the body were split exactly down the middle one side would be the duplicate of the other. A comparison of the four limbs proves that not only is the right arm similar to the left arm and the right leg to the left leg, but there is a close resemblance between the arms and the legs. In each case the upper areas are fleshier than the lower and all terminate in a flattened portion (hand or foot) ending in five digits—the fingers or toes as the case may be. The great toe and the thumb are very similar in constitution. Not only in outward appearance, however, are the limbs like each other; later on when we study the internal construction of the body, we shall find out that there is a wonderful duplication especially in the limbs of all the various muscles, bones and joints.

No two people are made exactly alike. First there is the predominating classification of sex, in which special organs, qualities and functions indicate the differences. Secondly there are the dissimilarities of texture, of the skin, of the hair, of the framework. Thirdly there are pigmentary characteristics, showing variations ranging from the darkest brown of the nigger to the milk-white of the Scandinavian; there are blue eyes and brown eyes and grey eyes; there are blondes and brunettes; there are fresh complexions and sallow complexions. In addition to all these different manifestations there are hundreds of minor deviations from the standard pattern, but despite them all the human race maintains an average type which is constant.

A knowledge of the normal sample is essential for those who take up the profession of nursing. A sick person is one who

demonstrates some abnormality of make-up or of function and it is obvious that a nurse cannot fully appreciate the disease unless she understands the body in its natural state of health. When a sewing machine or a typewriter goes wrong and we want to find out why we turn to the booklet of instructions sent with the machine when it leaves the shop. The diagrams and directions help us to obtain a clear idea of the complex mechanism and we may get to know our instrument so well that we can do satisfactory repairs ourselves. The same applies to nursing; the work of healing the sick cannot be successful unless the nurse knows the parts of the body and understands the way in which the work is carried on.

The Basic Elements of the Body

A closer naked eye inspection of the surface of the body shows that there are material differences of structure. For instance we find that the skin is hard and thick on the palm of the hand but thin and delicate on the lobe of the ear. The hair seems to be composed of something entirely different from the material of the nails. The covering of the lips and of the eyeballs is a film of rather fragile composition. There is an obvious difference in the touch impression received when we pass our fingers over a fatty area, a muscular area or a glandular area like the breast. Yet all these fleshy materials are made up from the same stuff. Just as raw cotton, or flax or jute can be manufactured into hundreds of different fabrics so the basic matter of the body can be affected or influenced by local needs; the result is the formation of bone, muscle, nerve, blood or skin.

If clay is thoroughly dried and ground up it resolves itself into a fine powder, the particles of which are apparent only when we employ special magnifying methods. From this powder we fashion bricks and the bricks in turn build the house. The body can be likened to a house: its bricks are called cells and the clay is known as protoplasm. Each cell consists of a collection of very minute particles, the inner ones free or rather loosely held together, the outer ones hardened into a thin skin or envelope called the cell wall. Millions of these cells unite and cooperate to form the substance of the body.

The Cell

It is well to have a clear conception of the nature and properties of the cell matter constituting the basis of our bodily structure.

Structure.—The cell has been under scientific investigation for many years and the knowledge of the subject is contained in hundreds of volumes. As time goes on we learn more and more

by improved microscopical technique and by the advancement of physical and chemical research. From the mass of facts which has accumulated certain definite points are outstanding.

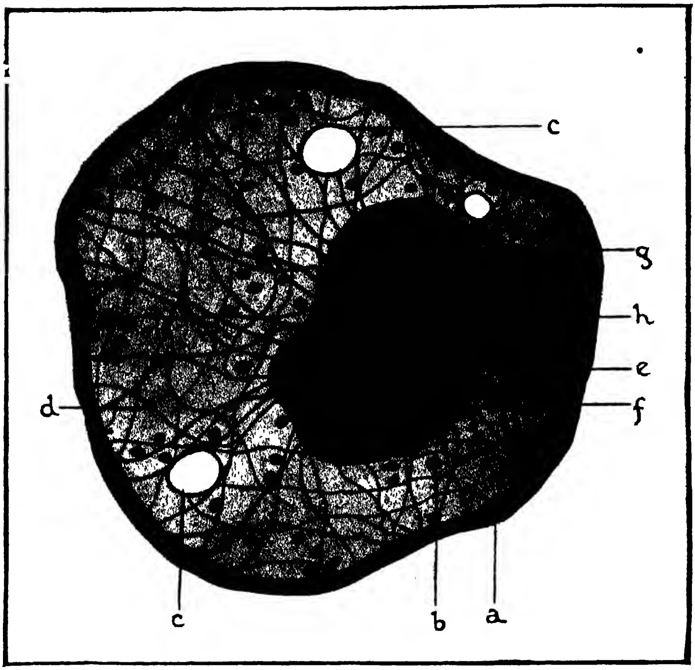
The first is that the cell consists of a rather unstable glutinous fluid like thin paste; it is lumpy here and there owing to the presence of little particles. Chemically this type of substance is known as a colloid; it consists of water in which is dissolved or suspended numerous constituents in a state of extreme refinement. There are also present starchy material, sugars, albuminous compounds, fatty substances and several other simple chemical compounds known as salts. There are about 20 basic elements in the cell, mostly combining in part to form the constituent materials of its substance. The most important are oxygen, hydrogen, nitrogen, sodium, calcium, magnesium, sulphur, chlorine, carbon, iron, potassium and phosphorus (Plate I, A).

The second important fact about the cell is that when we examine it under the microscope, using a high-power lens, we see not only the granules but also several fine little thread-like structures known as fibrils. These form a network which supports the more fluid protoplasm. Here and there little round and apparently empty spaces may be seen; these are called vacuoles. The envelope of the cell formed of thickened and hardened protoplasm can plainly be made out.

The third feature is also demonstrated by the high power of the microscope. This is the nucleus, a very important and very active portion of the cell. It appears as a small round darker portion not quite in the centre of the cell, and usually consists, like the cell of which it is a part, of a thickened envelope, a network of fibres and a quantity of fluid. One or two granular portions may also be present; these are called nucleoli.

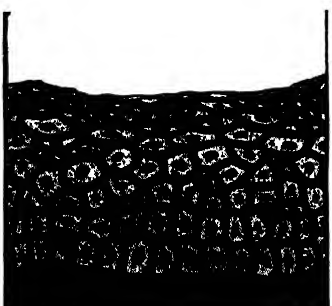
One other important constituent of the cell must be mentioned. Just outside the nucleus a small area may be seen, somewhat circular, and apparently composed of clear protoplasm in the middle of which two particles are situated. A mesh of delicate fibres surrounds this area. To the whole system is given the name centrosome. It is one of the most important parts of the cell. In addition minute bodies known as mitochondria are believed to play an important part in cell function, possibly giving rise to ferments which have influence on the growth and development discussed below. Mitochondria are seen as granules, rods or fine threads (filaments) scattered throughout the cell; when the cell divides, mitochondria are more or less evenly distributed between the two "daughter" cells.

Cell Division.—The centrosome is the origin of cell division or reproduction. This is the basic factor in growth and development of protoplasm. Most cells divide and subdivide until new



(A) SEMI-DIAGRAMMATIC ILLUSTRATION OF A NORMAL CELL OF THE HUMAN BODY.

a, Cell wall. *b*, Granule. *c*, Vacuole. *d*, Fibrils. *e*, Nucleus. *f*, Envelope of nucleus. *g*, Nucleolus. *h*, Centrosome.



(B) STRATIFIED EPITHELIUM, SHOWING VARIOUS LAYERS.

(C) TRANSITIONAL EPITHELIUM.

a, Layer of flattened cells. *b*, Pear-shaped cells. *c*, " Packing cells." *d*. Basement membrane.

CELLS AND EPITHELIUM.

masses are formed. In order to understand perfectly the characters of a living cell it is customary to observe the activities of one of the lowest creatures in the animal world. This organism, called the amoeba, is unicellular, can be kept alive and studied under the microscope and demonstrates all the principles of cell structure and cell energy which also obtain in the human cell viz. ingestion of nourishment, excretion, movement, growth and reproduction. Some cells do not possess the last property.

Cell Reproduction.—Each cell is formed by the division into two of a pre-existing cell known as the mother cell and the two new cells are referred to as daughter cells. The latter have all the characteristics of the mother cell. Human cell reproduction may be carried out in two ways: 1. direct (amitosis); 2. indirect (mitosis or karyokinesis). In direct division, which affects certain cells of the human body (white blood and bone cells), there is a simple fission of the nucleus after preliminary constriction, so that two new nuclei are formed. Each nucleus takes its share of the protoplasm and thus two completely independent replicas of the original cell are formed.

In indirect division, a method found chiefly in the higher animals, the process is more elaborate and of greater complexity. There are four phases—prophase, metaphase, anaphase and telophase, each representing a stage of activity. The main events are centred on the formation of wavy filaments called chromosomes, now universally recognized as the essential and constant elements, bearing and transmitting the inherited characteristics of the parents. It is impossible here to go fully into the mechanism of mitotic division, but further study by the nurse is well worth while.

The Formation of Body Tissues

The next step in the understanding of the construction of the body is a knowledge of the various groups of cells which, when massed together, are known as tissues. A tissue may be defined as a collection of specialized cells of identical origin, structure and function. Such specialization is represented by the function of the cell itself and of the mass of tissue concerned e.g. secretion of a fluid vital to the body.

As a preliminary measure it will be of assistance to know how a new creature begins and how life is generated from the earliest days of conception. The initial or parent cell, of every tissue and organ of the body is the ovum (or germ cell) of the female, after it has been penetrated (or fertilized) by the spermatozoon (or germ cell) of the male. It is unnecessary to go into further details of the physiology of conception; suffice it to say that immediately an ovum is fertilized it begins to divide rapidly into

other cells, which gradually take certain shapes and sizes according to their functions in the mature offspring. The study of growth from the ovum to the full-time child belongs to a special branch of science called embryology and need not concern us at this stage.

The Four Elementary Tissues

The basic tissues are 1. epithelium; 2. connective tissue; 3. muscle tissue; 4. nerve tissue.

The cells constituting each of these tissues have become endowed with certain properties which distinguish them from those of another group. With the exception of nerve tissue the basic tissues can be split up into several varieties, this differentiation depending upon the function appropriate to the tissue at a given spot. As mentioned above the cells become specialized for certain definite work, their protoplasm thus showing minor but distinct alteration. It is possible to recognize the variety of epithelium or connective tissue or muscle by examining the cell under the microscope.

With regard to the development of these individual groups of cells, the method is governed fundamentally by the laws of heredity and by the moulding influences of the womb. Assuming that the primary cell is a perfect sphere or globe, we might expect that the initial mass, after the first few subdivisions have occurred, would be a ball composed of similar daughter cells and this, indeed, is exactly what is produced. The term, mulberry mass, has been applied to the earliest embryo because it is studded on the surface with the protruding surfaces of the cells on its outer aspect. Naturally this formation cannot go on in an unrestricted way. Pressure has its effect, and just as the round chambers made by bees become hexagonal in the honeycomb, so the cells of the human being are shaped according to a certain pattern depending upon their situation. Some become flattened out like a pancake; some become pointed at both ends like a spindle; some become cylindrical; some become like stars. The nucleus may travel to the base of the cell or it may enlarge and occupy almost the whole of the cell. In certain cases the cell may develop special hair-like processes or long fibrils extending well beyond the usual boundaries of its envelope. By these methods many types of tissue are built up and elaborated. A study may now be made of the individual examples.

Epithelium

Suppose we wish to preserve a material such as the wood of a door. We apply in succession several coats of fine paint, making sure that each layer is smooth and evenly distributed. In order

to ensure a perfect finish we then add either enamel or varnish, so that the final coat is glistening and free from any traces of roughness. Epithelium is the varnish of the body. It covers all the important surfaces, inside and outside. It forms the outer coat of the skin, lines the stomach and intestines, spreads all over the inside of the tubes of the body, the air apparatus, the blood-vessels, the glands, the bladder, the inner chambers of the brain, the canal of the spinal cord. It may occur as a single flat layer of cells or as a coating several cells in depth. The cells are always found firmly attached to each other, there being usually a minimum amount of cement-like fluid. When there is only one layer of cells the tissue is called simple epithelium; when there are several layers the term, compound epithelium, is applied.

Simple epithelium is divided into 3 easily recognized varieties.

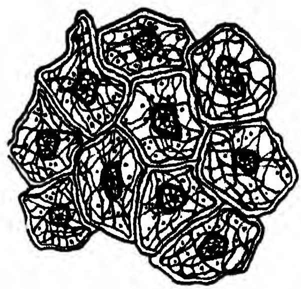


Fig. 1.—Pavement Epithelium.

1. **Pavement, or Squamous, Epithelium.**—In appearance the cells are flat platelets rather like an oyster shell in outline. Their size varies; when a layer is transferred to a microscopical slide and examined it is like a "crazy" pavement in pattern (Fig. 1). Sometimes the fibrils of the adjacent cells spread out like fine tendrils and help to bind the cells together. Pavement epithelium is found in the inside of the lungs; it lines the chambers of the heart, the blood-vessels and the lymphatic tubes; and it also forms a fine enamel for a tissue which is found in the abdomen and elsewhere and to which the name, serous membrane, is given.

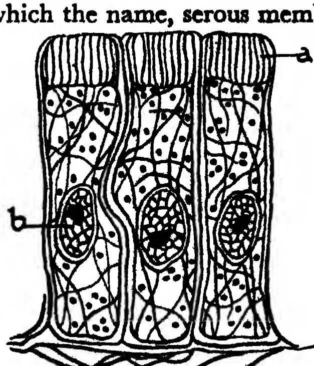


Fig. 2.—Columnar Epithelium.
a, Striated edge. *b*, Oval nucleus.

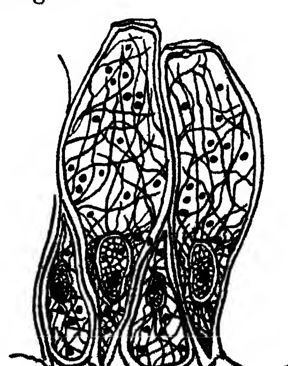


Fig. 3.—Goblet Cells.

2. **Columnar, or Cylindrical, Epithelium.**—In this variety the cells are like cylinders or rods; they are set up very much like the pipes of a pipe organ. The sides lose their rotundity by being pressed in the process of natural packing, common to all epithelium. The nucleus is oval and shows a well marked network. Usually there are striations at the top portion of the cylinders (Fig. 2). This variety of epithelium is found lining almost the whole of the stomach and bowels, including the associated glands; it also occurs in certain parts of the male and female reproductive organs. A columnar cell may have one or two slight modifications; in some tissues it assumes a cup-like shape and manufactures a glairy fluid called mucin; such cells are called goblet cells or chalice cells (Fig. 3).

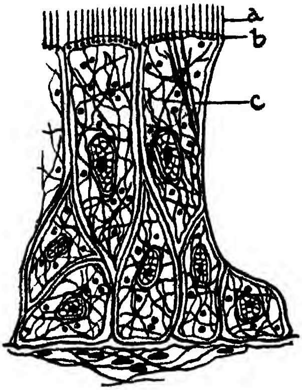


FIG. 4.—CILIATED EPITHELIUM. *a*, Cilia. *b*, Basal nodes. *c*, Shows how the cilia are fixed.

3. **Ciliated Epithelium.**—The word, cilia, in Latin means "the eyelashes." Ciliated epithelium is epithelium provided with fine hair-like processes forming a sort of fur on the top of the cylinder (Fig. 4). This is illustrative of one of the great steps in early specialization of protoplasm. These ciliated processes, which are fixed to the "lid" of the cell by small knobs, are deeply rooted in the cell matter and it has been proved conclusively that they lash about in rhythmic fashion, very much like the feathers of a fan when it is in use. The result is a clearing of the atmosphere which immediately surrounds the cells. A further example of how the work is done is provided by the treatment of the spectator who has collapsed in the middle of a big football crowd. Those who have seen the method of "passing over" will have no difficulty in imagining clearly the action of thousands of cilia on a minute particle.

The importance of this type of epithelium cannot be overestimated. It is found lining the nose, the windpipe, the bronchial tubes, the inside of the ear, the womb, the uterine tubes, certain parts of the male generative organs and the central portions of the brain and spinal cord.

Compound epithelium has two main subdivisions; these are discussed below.

1. **Stratified Epithelium.**—The cells are in several layers built up like the stones of a wall, one on top of the other. The deepest layer rests on a thin membrane called the basement

membrane; the cells are columnar in type. As we pass from the deep to the superficial layers, we note that the cells gradually become flattened, as if they had been subjected to considerable pressure from above. The layers of cells become like fish scales, overlapping each other and very much thinned (Plate I, B). When a cell from the deeper layers is isolated it shows little outgrowths or spicules of protoplasm. The cause of this is clear; these deeply placed cells are not cemented together like the simpler forms of epithelium. Between each cell is a little channel, traversed by these tiny outgrowths of protoplasm, so that when the cells are separated little spikes are left, giving to this peculiar variety of epithelium the name prickle cell (Fig. 5).

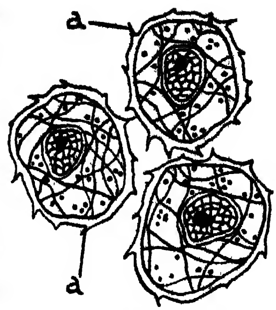


FIG. 5.—PRICKLE CELLS WHICH HAVE BEEN SEPARATED.

a, Spines of protoplasm.

A good example of stratified epithelium is the epidermis of the skin, which demonstrates four distinct layers. This type of epithelium also occurs on the surface of the eyeball and inside the mouth, the gullet and the vagina.

2. **Transitional Epithelium.**—Perhaps this is the most interesting variety of epithelium, not only on account of the fact that it is to be found in one area of the body only but also because its function makes it adaptable to expansion and contraction. Transitional epithelium lines the urinary bladder and the tubes leading from the kidneys to the bladder. Three elements enter into its composition (Plate I, C). The first is a layer of cells which are pear shaped, with their points towards the basement membrane; the second is a layer of cells lying somewhat flattened out on the broad ends of the "pear" and showing indentations at the points at which they are in contact; the third type of cell, smaller and less well defined, acts as a sort of "packing" between the pear cells. The usefulness of this grouping can well be realized when we consider that the bladder acts as a reservoir for the slowly collecting urine of several hours. As the bladder fills up it is an easy matter for the epithelium to expand and yet to retain its function as an internal varnish.

Connective Tissue

Epithelial tissue represents the simplest form of cell accumulation. A stage further in the evolutionary progress is the formation of connective tissue. Like epithelium, the latter begins with simple cells but the demands of development stimulate the cells to

elaborate their composition and function, thus producing a tissue more highly organized than is simple or compound epithelium.

Generally speaking connective tissue is the framework of the body; its cells are endowed with the function of supporting and uniting other groups which have more highly organized tasks to do in the active work of the body. There are many varieties of connective tissue but whereas they have the same origin and the same type of parent cell, individually they reach such a complex state of specialization that one variety of connective tissue may appear to bear no resemblance to another. There is one important and definite property common to all connective tissues: the basic matter of the tissue is developed outside the cell. The basement substance (or matrix as it is called) is a very fine flimsy network of delicate threads formed out of the protoplasm. In the substance of the matrix the cells can be seen to be set at some distance from each other; between them and running in all directions are bundles of wavy fibrous or elastic tissue. The types discussed below depend upon differences either in the cells or in the fine basic network with its fibres.

Areolar Tissue.—This tissue contains examples of most of the stock elements of connective tissue in general, therefore it is often used as the representative member of the whole group. It is characterized by the presence of comparatively large air spaces which communicate with each other. The matrix is formed by a fairly thick type of fluid and when we examine it under the microscope we find a rather finely woven fabric of silky appearance, with stronger strands of fibrous and elastic tissue running in all directions. There are often as many as 6 different types of cell; some have branching processes like antlers, some may be perfectly spherical, some may be moulded so that they fit their neighbours like the parts of a jig-saw puzzle; in many cases the outgrowths clasp the adjacent cells.

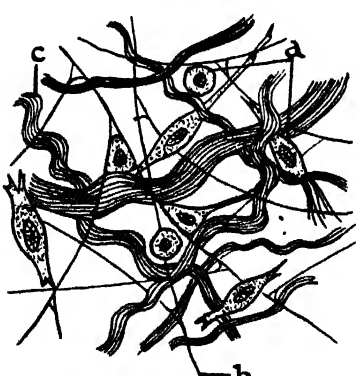


FIG. 6.—AREOLAR TISSUE.
a, Cells. *b*, Network. *c*, Fibres.

Areolar tissue acts like a very fine cement; it is the mortar of the body, akin to the finest adhesive plaster. Its power of elasticity makes it able to accommodate itself to movements of the organs with which it is associated. Its chief situation is immediately below the skin, underneath the lining of the stomach

and intestines and below the outer covering of the digestive tract. It is used to bind loosely together nerves, blood vessels and muscles. In fact it may be said that if there is any part of the body in need of a general fixative and packing for loose spaces areolar tissue supplies the wanted material (Fig. 6).

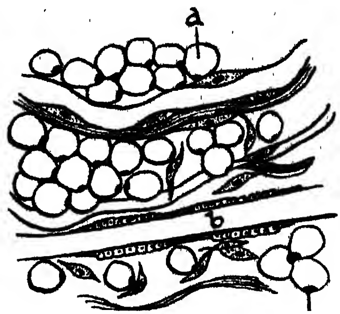


Fig. 7.—Adipose Tissue.
a, Fat cells. *b*, Blood vessel. *c*, Nucleus.

Adipose Tissue.—It is an easy transition from areolar tissue to adipose tissue, or fat. Indeed there are very few areas containing areolar tissue in which fat is not present; fat originates in areolar tissue. The development of the fat cell begins in an ordinary connective tissue cell. At a stage in the growth of the embryo, several distinct drops of an oily matter made up of palmitin, olein and stearin may be observed in the protoplasm of the connective tissue cell. Gradually these droplets merge and form one big drop of fat which not only occupies the cell but seems to make it bulge. When several millions of these cells are grouped together we find a mass of adipose tissue or in more homely words, a piece of fat. Fat is in liquid form in the living person but it becomes solid after death occurs. It tends to accumulate, as many know to their cost, in the abdomen and in certain other parts familiar to all. It may increase uniformly, as in the obesity diseases. Fat is not found in the eyelids, cranial cavity, certain parts of both male and female generative organs and the lungs. It is useful in acting as a support for the kidneys, which are embedded in adipose tissue. Bone marrow contains a large percentage of fat (Fig. 7).

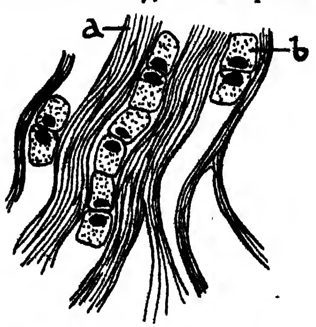


Fig. 8.—Fibrous Tissue, from a Tendon.
a, Fibres. *b*, Cells.

Fibrous Tissue.—This is one of the strongest fabrics of the body. It is a connective tissue in which white fibres predominate. These fibres can be seen, very like carefully combed locks of hair, running in bundles or intersecting each other (Fig. 8). The cells of this tissue tend to become built up into columns; each cell sends

out little outgrowths which dip like fine roots between the bundles of fibres.

Fibrous tissue is the material basis of tendons, which connect muscles with bones. It also forms the ligaments, which fix bones together at joints, acting like leather hinges. The important membranes which cover bones (periosteum) and muscles (fascia) consist also of fibrous tissue. Its properties are those of the sinew, which with its glossy whiteness is hard, firm, resistant and lacking in elasticity. Large quantities of gelatin are extracted when white fibrous tissue is boiled.

Elastic Tissue.—This form of connective tissue is explained by its name. Instead of white fibres which as already stated are predominant in fibrous tissue, there are bands of yellow fibres, like thin rubber strands. This tissue has the power of great expansion but it always contracts to its original size when required to do so. Sometimes the elastic fibres are so large that they seem to occupy the whole of the matrix. Elastic tissue occurs in the vocal cords and in certain other parts of the upper respiratory passages, in the coats of the great blood vessels and in certain ligaments of the spinal column where much elasticity is necessary.

Lymphoid Tissue.—The distinguishing feature of this type is found in the matrix, which is almost entirely fluid, making the tissue very watery and soft. There is a most delicate network of fine fibrous threads, containing numerous round lymph cells. Lymphoid tissue is found in the tonsils, in certain glands and in the mucous membranes. There are slight variations, known as reticular or retiform tissue, adenoid tissue and so on.

Mucoid Tissue.—This is a type of tissue which occurs in "Wharton's jelly," a substance forming the bulk of the umbilical cord, or navel string, of the developing child. It also occurs in the pulp of the milk teeth and in the vitreous humour of the eye. Mucoid tissue is composed chiefly of a substance called mucin, in which are found a few branched cells.

Pigment Tissue.—In certain parts of the human body dark patches of pigment occur which may or may not be associated with disease. This condition is more marked in those of dark complexion and may be found in the freckles of the skin, in the eye, in moles and in a small area surrounding the nipples. On analysis the tissue is found to contain pigmented connective tissue cells; these are branched and contain numerous dark brown granules of a substance called melanin.

Cartilage or Gristle.—This tissue represents a further stage of advancement in the evolution of specialized fabric of the body. The matrix is quite solid and the constituent cells are, so to speak, imprisoned or embalmed. Cartilage is the forerunner of bone;

when the child is developing in the womb nearly all the skeleton consists of temporary cartilage which afterwards changes into bone. Chemically cartilage is composed of chondrin, which is akin to gelatin.

Like fibrous and elastic connective tissue, cartilage is found in places at which great strength is required. A certain amount of play is provided for, so that the tissue is a very suitable transitional material for the bones. There are 3 chief types: 1. hyaline cartilage; 2. white fibrocartilage; 3. yellow elastic fibrocartilage.

Hyaline Cartilage.—In this tissue there are neither blood vessels nor nerves. It is found at the ends of the bones covering the areas which meet when a joint is in action and appears as a white, smooth-surfaced tissue, tinged with light blue. Except at the ends of the bones, it is always covered with a nourishing membrane called the perichondrium. Under the microscope, the tissue has the appearance shown in Fig. 9. It will be noted that the cells usually lie in pairs, fixed in a matrix which is almost clear and which seems to form a sort of capsule round the space in which the cells lie. This variety of cartilage comprises the cartilage of the ribs and most of the joints; temporary cartilage is always of the hyaline variety. The characteristics of this tissue are a great amount of resiliency so that it acts as a pad and shock-absorber at the points at which bones meet and press on each other. Its smooth surface allows perfect facility of movement. In the rib cartilages, fibrous strands and deposits of chalky salts appear with the advance of old age. Hyaline cartilage occurs in the nose and in certain parts of the wind-pipe.

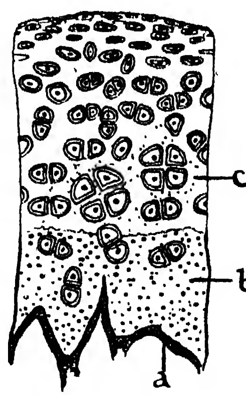


FIG. 9.—HYALINE CARTILAGE FROM END OF BONE.
a, Bone area. *b*, Transitional area. *c*, Hyaline cartilage with cells.

White Fibrocartilage.—The difference between this tissue and the hyaline type is that fibrocartilage, as its name implies, has fibres running in the matrix. The cells are roughly egg-shaped and are encapsuled, there being no fibres in the immediate neighbourhood of the cells (Fig. 10).

There are 5 chief divisions of fibrocartilage. The interarticular variety is found as padding between bones, occurring at the wrist, collar bone and knee. At the last situation it is well known to be troublesome to athletes and footballers. The connecting fibrocartilages are those which exist as leather-like discs between each bone of the

FIG. 10.—FIBROCARTILAGE, SHOWING CELLS SURROUNDED BY FIBROUS STRANDS.

spine; in this variety there are strong fibres. Other types are (1) those used for deepening joint cavities e.g. the hip and the shoulder, (2) those which line the grooves occupied by tendons and (3) those which occur at the point at which the lower jaw moves on the temporal bone of the head.

Yellow Elastic Fibrocartilage.—This is the type found in the ears, in the windpipe and in the little trapdoor—the epiglottis—which guards the entrance to it. Microscopically the tissue is very like fibrocartilage, except that the matrix is crowded with yellow elastic fibres.

Bone.—Perhaps bone is the most important of the connective tissues, since it is the hardest, the most resistant and the most fundamental in the framework of the body structure. It is easy to imagine how bone is formed from cartilage; an already hard and tough matrix is made still more solid by the addition of granules of certain mineral substances.

Bone is made up of both animal and inorganic matter. One-third of its total weight is due to the presence of the former, which is of a gristly nature and can be demonstrated by soaking a bone in a weak acid, the latter dissolving the mineral substance and leaving an elastic, easily bent structure which preserves all the features of a hard bone. Two-thirds of bone consist of a combination of calcium and phosphorus—phosphate of lime, carbonate of lime, magnesium phosphate and several other salts.

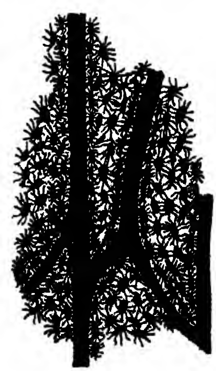


FIG. 11.—HAVERSIAN CANALS CUT LONGITUDINALLY, SHOWING BRANCHING.

On naked-eye examination bone is pink on the outside, but the colour deepens as we approach the centre of the bone. If a bone is sawn transversely the section shows an outer casing of a very dense substance like ivory; this is called the compact bone. Underneath the latter is the cancellous bone, resembling a honeycomb or sponge and formed of a lighter type of bony material. There is no intrinsic difference between the compact and cancellous portions. They vary only in the concentration of the material elements;

both contain many canals and pores. A light bone has more spongy tissue than a heavy bone and vice versa. All bones are covered by a nutritive membrane called the periosteum which conveys and distributes blood to the bone matter through little canals. In long bones there is a central canal containing marrow. This substance also occupies the spaces in the cancellous tissue. Bone is supplied with blood vessels, nerves and lymphatic channels.

The microscope provides a picture which is typical and which is always easily recognized. The tissue is divided into circular areas called Haversian systems. They are rather like the discs of a pineapple cored and prepared for the table, showing numerous concentric rings and an oval area in the middle, which is called the Haversian canal. The rings are composed of bone matter and are known as lamellae. At intervals between the rings are spaces known as lacunae, which contain flat, branched and nucleated bone cells; these spaces communicate with the central canal by channels which radiate in all directions—the canaliculi. Fig. 11 illustrates a bone cut longitudinally, and Fig. 12 a bone cut transversely in order to show the system in two planes. The Haversian systems form long cylindrical rods which may communicate with each other; between these columns there is a "padding" of lamellae and bone cells. Haversian canals contain vessels and nerves. The lamellae have a matrix of white fibres supporting the finest particles of calcium phosphate.

Ossification.—This is a term used to describe the formation of bone either from cartilage or from a membrane. In cartilaginous ossification a "model" or cast is already in existence, formed of hyaline cartilage. Bone formation starts at the centre of the mass but secondary centres are in operation soon after at the ends of the bones. Meanwhile there is also activity at the perichondrium, which lays down parent cells of bone, the osteoblasts. These form a layer of thin bone surrounding the cartilaginous cast. This occurs at the same time as a shrinkage and death of the central cartilage cells goes on. The outside of the frame is strengthened whereas

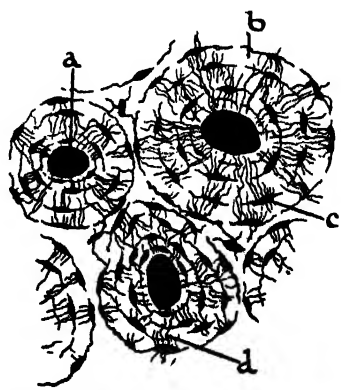


FIG. 12.—BONE, SHOWING HAVERSIAN SYSTEMS.

a, Haversian Canal. *b*, Lamella. *c*, Lacuna. *d*, Canaliculus.

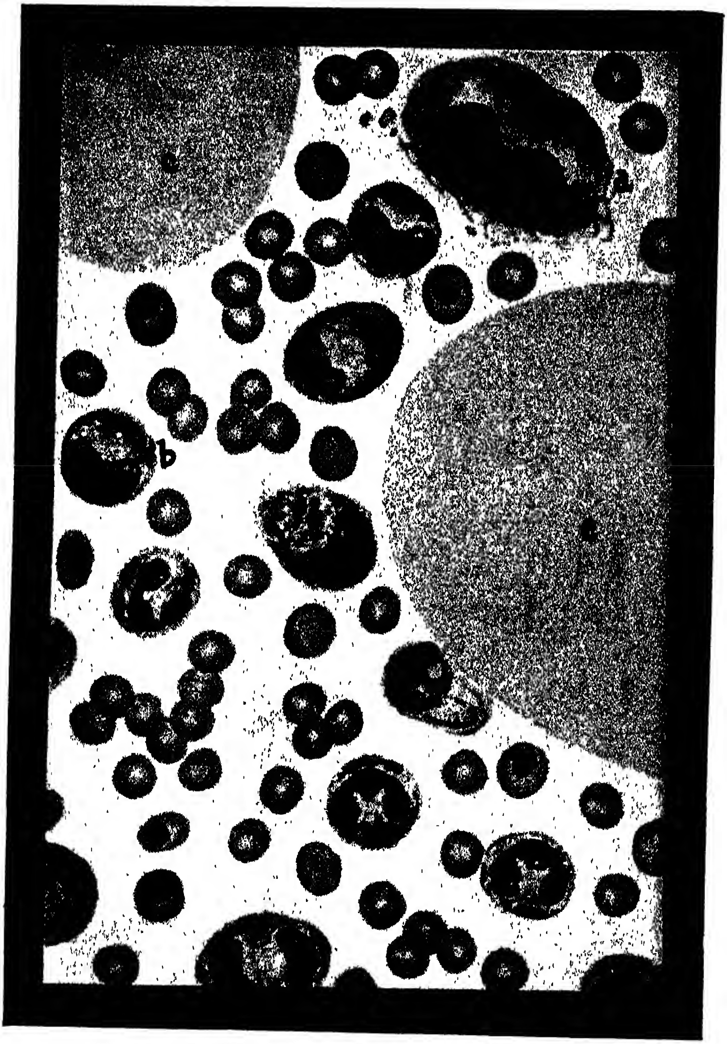
the core is weak and full of holes left by the withered cartilage cells.. Fine beams of bone are laid down; this is the origin of cancellous bone. The perichondrium has now become the periosteum.

A second type of cell, the osteoclast (or bone destroyer) is generated from the membrane. It bores through to the centre of the framework and by its action dissolves the temporary beams, leaving bigger chambers with stouter bony walls which later contain the marrow. The initial central portion of growing bone is called the diaphysis; secondary centres at the ends of the bones are known as epiphyses. So long as ossification is going on, a pad of cartilage remains between the diaphysis and epiphysis. This is called the epiphyseal cartilage. On its activity depends the growth of the bone in the long axis. In studying the tissues of a growing bone, therefore, we should expect to find all stages in bone development, from true hyaline cartilage to mature bone. Secondary centres of ossification begin at the ends of the larger bones and the bone-forming routine goes on exactly as in the primary centre. Thus in a normal bone of a young adult we find a central area of activity, several centres at the ends and areas of epiphyseal cartilage. Once the bone has stopped growing completely, the temporary cartilaginous elements disappear for good. The bone increases in thickness by deposition of layers from the under-surface of the periosteum. All these facts are most important in injury or disease.

Ossification from a membrane occurs in a different way, and is found in the flat bones of the skull. First of all there is a framework of connective tissue formed of fibrous strands, blood-vessels and osteoblasts. Between these fibrous threads little granules of bone are laid down until a firm bony layer is formed. Ultimately the fibres are destroyed and the bone develops by the building up of one layer of new bone on another.

Bone Marrow.—There are two types of marrow, the yellow and the red. Marrow is well known as the pulp found in the inside of bones; it occupies both the canals and the cancellous spaces. Yellow marrow consists of blood vessels and cells (chiefly fat cells) supported by a fine network of connective tissue. It occurs in the shafts of bones. Red marrow is found in flat bones, at the enlarged ends of long bones and in the ribs, sternum, vertebrae, cranial bones and short bones. It has the same basis as yellow marrow but the predominating cell is the myelocyte, or marrow cell. This resembles the white blood cell. The red marrow is the nursery of the blood. The red blood cells take origin from various types of parent cell present in its structure (Plate II).

The blood and the lymph are two types of connective tissue.



FILM OF BONE MARROW.
a, Giant cells. *b*, Myelocytes. *c*, Fat

but they are more conveniently studied with the circulatory system. (See pp. 145, 176.)

Muscular Tissue

The muscles form the main fleshy portions of the body. Muscle tissue consists of bundles of red fibres which have the power of contraction. As a result of this property a group of these fibres, enclosed in a sheath to form an individual muscle, may by concerted action shorten or elongate, thus causing movement of the bones at the joints. This is the whole principle of body action. All muscles possess a certain tone, a term used to describe a state of semi-contraction allowing full contraction to occur at the shortest possible notice. Life and alertness depend upon this property; the tone is increased in strain, and this explains many of the problems of fatigue and exhaustion.

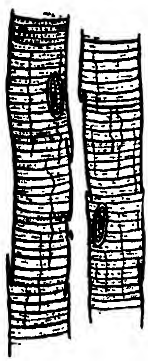


FIG. 13.—VOLUNTARY MUSCLE FIBRES, SHOWING STRIATIONS AND NUCLEI.

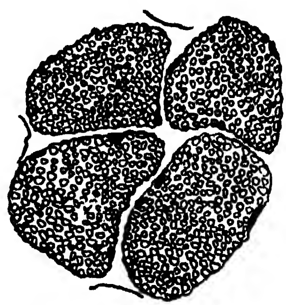


FIG. 14.—A SECTION THROUGH MUSCLE SHOWING FIBRES IN FASCICULI.

Three-quarters of muscle is water. Of the remaining quarter, nitrogenous matter, fat, gelatin and mineral salts form the mass. The contractile element lies in the muscle plasma, a fluid which is capable of coagulation.

Varieties of Muscle.—Three types are clearly defined as follows: 1. striped or voluntary muscle; 2. unstriped or involuntary muscle; 3. cardiac muscle.

Striped Muscle.—This forms the main muscles of movement and is concerned with the action of the body; it is the basis of flesh. Striped muscles are controlled directly by the will, therefore they are also known as voluntary muscles. Under the microscope the fibres show numerous horizontal striations; the

fibres are arranged in bundles like faggots, hence the term, fasciculi. Round each bundle is an enveloping sheath of connective tissue which sends in little partitions cementing the fibres. An aggregation of fasciculi forms a muscle. The individual fibre is a sheath, or sarcolemma, containing the muscle plasma (Figs. 13 and 14). Contraction of muscle is carried out by alterations of the plasma, a very complex process depending upon stimulated protoplasmic movement. All muscles are abundantly supplied with blood vessels and nerves.

Unstriped Muscle.—Most of the digestive tract is provided with unstriped muscle. The latter also occurs in certain parts of the windpipe and in the gall bladder, the kidney and urinary bladder, the sexual organs, the skin, the spleen, mucous membranes, sweat glands, breasts and blood vessels. The fibres are bundled together in much the same way as those of striped muscle. The essential difference is that there are no transverse stripes. The tissue is often called plain muscle on that account. The fibres are nucleated and shaped like an elongated spindle. There are faint vertical lines (Fig. 15). This muscle tissue causes rhythmic contractions, independent of the mind, to occur in the digestive tract; it also responds to a certain distension of the bladder and rectum and thus governs the normal evacuations.

Cardiac Muscle.—This tissue is peculiar to the muscles of the heart and enables that organ to perform a very special function. It is neither striped nor plain muscle although it has the characteristics of both. First of all the striations run in both directions; the outline of the cells is vague. There is no sarcolemma and the connective tissue is reduced to a minimum. Heart muscle is contractile, but the will has no influence on it. The heart contracts in waves which pass from its base to its apex, but the property appears to be inherent in the muscle cells; under the influence of emotion, grief, excitement or physical strain the frequency of these fibre-contractions, and therefore of the whole heart, is increased; hence palpitation is set up, but in the normal course of events the beating of the heart is a matter of steady perpetual motion which is only interrupted at death (Fig. 16).

FIG. 15.—PLAIN MUSCLE CELL, SHOWING LONGITUDINAL STRIATION AND SPINDLE SHAPE.

Nervous Tissue

Nerve tissue consists of cells and in certain areas of a basic substance called neuroglia. The cells send out long streamers or processes to which

the name, nerve fibres, is given. If we examine nerve tissue with the naked eye, there appears to be a light area and a dark area. The former is made up almost entirely of fibres, and is known as white matter; the latter consists chiefly of cells and is called grey matter. Nerve cells cannot reproduce themselves; once they are destroyed they cannot be replaced.

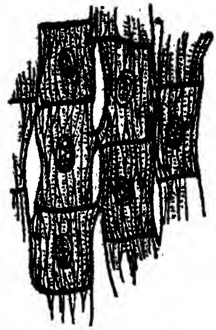


FIG. 16.—HEART MUSCLE.

Nerve tissue is found in the brain, spinal cord and all the nerves, including certain centres called ganglia. It is the most highly specialized tissue of the body, acting like a telegraph system which links up the organs and tissues and coordinates the body as a whole. The cells may be likened to the offices, in which sensations are received and sent out; the fibres are the wires along which the sensations travel. Apart from the neuroglia, which is like connective tissue with branching cells and fibres, the true cells of the nervous system are found in the grey matter. A nerve cell may be unipolar, bipolar or multipolar, according to the number of processes which proceed from it. The multipolar variety is the commonest; the cells are shaped like a star or a pyramid. Two varieties of outgrowth are recognized: 1. the axon or axis-cylinder process, which goes to form a nerve, and 2. the dendrite. The dendrites may be very numerous; as soon as they emerge from the cell they branch like a tree and ramify over a comparatively wide area. The nerve cell or cyton has a basis of fine fibres and minute granules are also found, especially in the region of the nucleus. Other very important granules, the Nissl's bodies or spindles, are scattered throughout the protoplasm; these are said to increase during mental activity and to disappear after fatigue. Their value in research cannot be overestimated; they are frequently regarded as the index of mental fitness (Fig. 17).

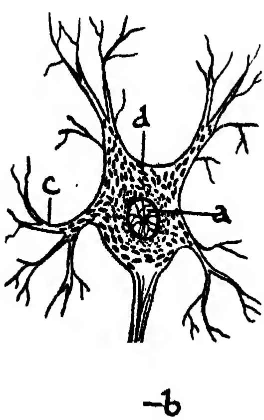


FIG. 17.—PYRAMIDAL NERVE CELL.

a, Nucleus. *b*, Axon. *c*, Dendrites. *d*, Nissl's bodies.

The nerve fibres occur in the nerves

and in the white matter of the brain. Medullated fibres consist of a central portion (*a*) and enclosed in a thin neurolemma or primitive sheath (*c*) of an enveloping sheath (*b*), which is deficient at intervals, forming an isthmus called Ranvier's node (*d*) (Fig. 18). The central portion, or axis cylinder, which is derived from the axon of a cell, is the vital part of the fibre. It is never interrupted from the time it leaves the cell until it terminates in the skin, muscle or elsewhere. The enveloping sheath is fatty in nature and is regarded as protective to the axis cylinder. It is frequently likened to the insulating matter of an electric wire. Non-medullated fibres occur chiefly in the part of the nervous system known as the sympathetic system; they are called Remak's fibres and consist of a nucleated axis cylinder.

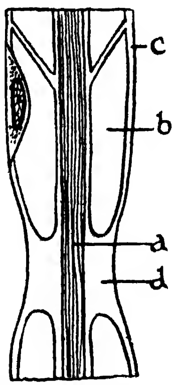


FIG. 18.—MEDULLATED NERVE FIBRE.

Showing, *a*, Axis cylinder. *b*, Medullary sheath. *c*, Primitive sheath. *d*, Node of Ranvier.

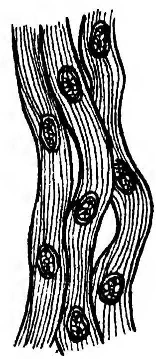


FIG. 19.—FIBRES OF REMAK (NON-MEDULLATED) WITH NUCLEI.

They are yellowish grey in colour (Fig. 19). The arrangement of the nervous system and its mode of action is discussed later (see pp. 244–272).

The Organs of the Body

With such a variety of cells, fibres and tissues at its disposal, the body is able to utilize each type in its most appropriate situation, thus the next step in the building of the frame is the construction of organs. An organ may be defined as a structure consisting of tissues in a mould most convenient for the efficient performance of a specific function. Thus the heart is built up

into chambers, valves and tubes, a complex pump which maintains the circulation of the blood; the kidneys are composed of cells which extract the liquid waste products from the body; they contain a machine which ensures the passage of urine into the bladder; the brain is a central bureau of thought, sensation and action, controlling all the work of the body.

The Systems of the Body

Organs rarely do their work without several partners. In carrying out the main functions of the body various organs act in conjunction, like the vital parts of a machine. When these organs are associated for a fixed purpose, the group is called a system. Certain systems are clearly defined and easily recognized; a list is given below.

The Bony System, or Skeletal System, the basis of the science of Osteology;

The Joints—Syndesmology;

The Muscular System, the foundation of Myology;

The Blood, Heart and Vessels; the Vascular or Circulatory System, comprised in Angiology;

The Brain, Spinal Cord and Nerves, forming the Nervous System, dealt with under Neurology;

The Respiratory System, dealing with the breathing;

The Digestive System, including the liver, pancreas and other organs which act in concert to break up the food and use its nutritive elements as well as disposing of waste matter;

The Excretory System, which disposes of liquid waste;

The Endocrine System, a collection of minute and powerful glands, the juices of which control many aspects of growth, reproduction and function;

The Reproductive System, different in each sex, a set of organs specialized for generation.

The last stage in the construction of the complete body is the arrangement of systems and organs in regions. There are several cavities in the body, bounded by bone and muscle, but it is more convenient to discuss this subject (Regional Anatomy) after dealing with the systems individually (see p. 296).

The Functions of the Body

The working of the bodily machine is founded on simple principles but by evolution all sorts of devices have been gradually added so that the performance of a function is very complex. Every system depends upon its fellows and perfect health depends upon 100 per cent efficiency. It is interesting to observe how much compensation there is for defects: the

wear and tear of life is so great that very few of us are without some abnormality; thus the interdependability of the systems is plain. It is very difficult to explain life, or the so-called vital force that prompts us in all directions. As far as we can see, our main function is to keep the body at a certain necessary state of warmth, and to this end we take fuel in the form of food which undergoes a slow process of combustion in the body, producing heat and repair material for worn structure. The energy of movement is also supplied by the food but movement itself may be simply a means to keep up the body heat.

Definitions

Technical terms abound in all sciences and medical science is full of descriptive nomenclature. Although it is better to avoid too much use of these names it is essential to know the principal ones.

First the divisions of medical science. Anatomy is the knowledge of the structure of the body, the naked eye appearances of the various organs, regions and their relations. Histology is the science of minute anatomy; it concerns the microscopical appearances of tissue. Physiology deals with the functions of the body. Pathology comprises all the knowledge of disease in tissues. Embryology deals with development of the unborn creature.

Secondly we must know the relative positions of the body. When we describe an anatomical position, we assume that the body is standing facing us, the legs together, the arms by the sides, the palms turned towards us. If we divide the body into equal right and left halves, we say we are dividing it in the mesial plane.

Anterior and posterior simply mean front or back; another name given to anterior is ventral, and to posterior dorsal. Superior and inferior indicate upper and lower respectively; in the limb the relative terms are proximal and distal. Medial means nearer to the mesial plane; lateral farther from the mesial plane. Superficial structures are nearer the surface than deep structures. External usually means the outside of a cavity, internal the inside. In certain regions, special words are used. Palmar is applied to the palm of the hand; plantar to the sole of the foot.

Terminology has been altered from time to time in the past 50 years. This has led to confusion, since each generation of students has used a different nomenclature. An attempt was made in 1895, after conferences at Basle in Switzerland, to set up an international system of nomenclature, this resulting in the publication of the terminology known as the *Basle Nomina*

Anatomica (B.N.A.). Since then, however, further revisions have been made, especially the Birmingham Revision (B.R.), certain terms of which are now in common use. Nurses are referred to the summary of anatomical terms (see pp. 303–306).

CHAPTER 2

THE SKELETON—INTRODUCTION

NUMBER OF BONES IN THE BODY. GROUPING OF BONES. THE NOMENCLATURE OF BONES.

In the building of a ship the first thing to be laid down is the keel; it is the foundation of the vessel. From the keel strong steel girders and crossbeams are put together until a shell is formed of the hull and body. Finally the various fittings are put in position—boilers, pipes, machinery and furnishings. The framework of the body is very like that of a ship except that the material used is bone, supplemented here and there by cartilage. The vertebral column, or backbone, is the basis of the frame and the girders and crossbeams are represented by the ribs and the bones of the head, limbs and pelvis (Fig. 20).

The function of the skeleton is that of protection and support; in addition to this the bones of the limbs are the bases of the organs of locomotion. Every bone shows prominences or rough areas corresponding to the attachment of muscles which pass from one bone to another and give the limb power of movement. The ribs form with the breast-bone, or sternum, a barrel-shaped cavity in which lie many vital organs such as the heart and the lungs; the pelvis is a bony cup-shaped cavity with wide rims supporting all the important structures of the abdomen.

Number of Bones in the Body.—There are 206 bones in the adult human skeleton. It is easy to divide the skeleton into two portions as follows:

(1) The Axial Skeleton, which consists of the skull (head and facial bones), the spine, the ribs, the sternum and the hyoid bone.

(2) The Appendicular Skeleton, which comprises the bones of the limbs and which is formed of 4 sets of bony systems.

In tabulating the bones, the grouping is as follows:

Skull	22
Spine	26
Ribs	24
Breast-bone	1
Hyoid Bone	1
Upper Limbs	64
Lower Limbs	62
Bones of the Middle Ear	6
Total	206

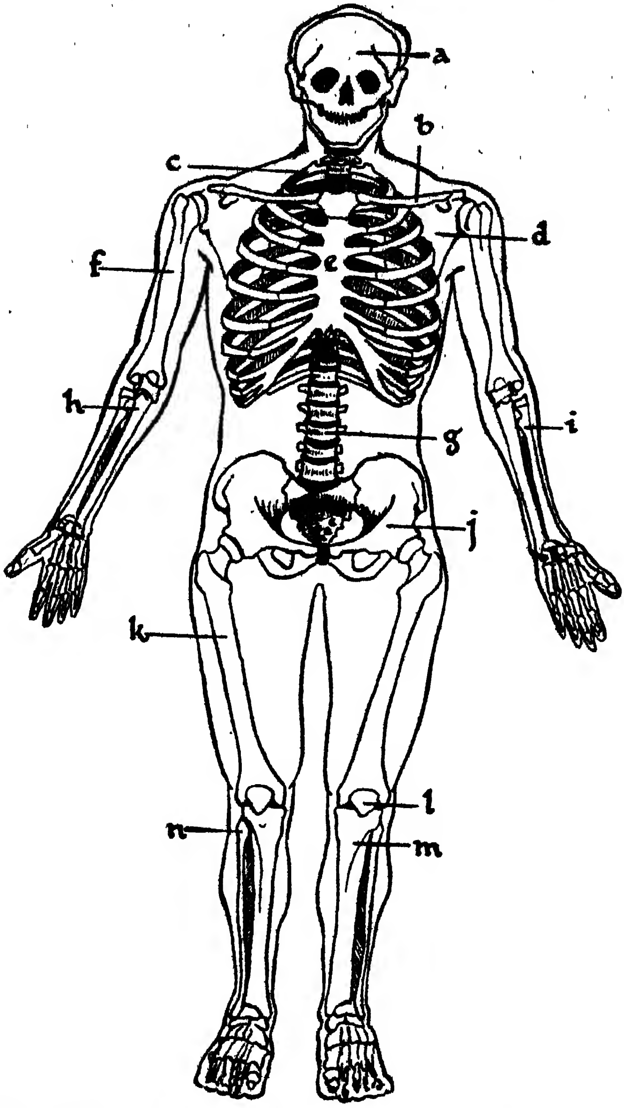


FIG. 20.—DIAGRAM SHOWING SKELETON AND OUTLINE OF THE BODY.

a, Skull. *b*, Clavicle. *c*, Rib. *d*, Scapula. *e*, Sternum. *f*, Humerus. *g*, Spine. *h*, Ulna. *i*, Radius. *j*, Pelvis. *k*, Femur. *l*, Patella. *m*, Tibia. *n*, Fibula.

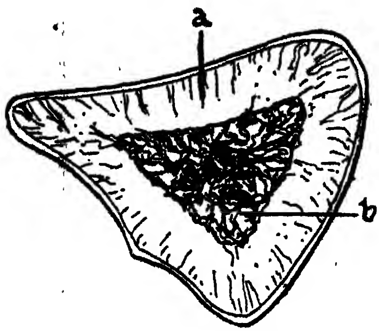


FIG. 21.—TRANSVERSE SECTION OF THE ULNA BONE.
a, Compact tissue. *b*, Cancellous tissue.

Grouping of Bones.—There are variations in the type of bone required for certain functions and it is convenient to divide bones into the 4 main classes described below.

1. *Long Bones.*—These bones, which act as levers for movement, are found in the limbs and consist of a shaft and two ends or extremities. In our study of the histology of bone we obtained a knowledge of the composition of bony substance and marrow. A long bone is fundamentally a compact, hard tube, whose walls vary in thickness, becoming thinned as they approach the extremities. Inside the tube is the marrow, or *medulla ossium*; the hollow portion of the tube is known as the medullary cavity. The spongy tissue of the bone gradually increases towards the ends, where there are knob-like enlargements with a core of spongy tissue supporting a quantity of red marrow (Figs. 21 and 22).

2. *Short Bones.*—In this class the bones are specialized for strength, support, a slight amount of movement and lightness; such bones usually fit into a minimum space. They have a thin shell of compact bone, the rest of their structure consisting of spongy tissue. Short bones are found in the wrist and in the arch of the foot.

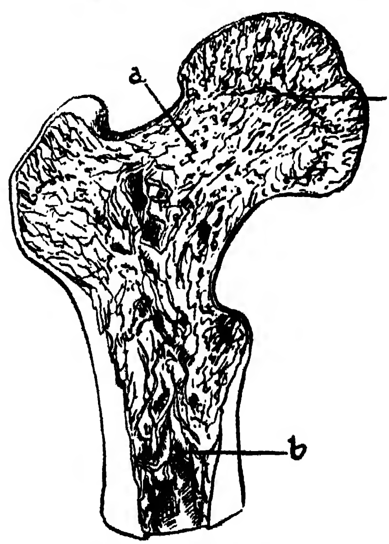


FIG. 22.—LONGITUDINAL SECTION THROUGH THE HEAD OF THE FEMUR.
a, Compact tissue. *b*, Cancellous tissue. *c*, Epiphyseal line.

3. *Flat Bones.*—These are bones which consist of two layers of compact substance, separated by an irregular layer of spongy bone. In con-

struction a flat bone resembles a sandwich. Its functions are to protect vital areas like the brain cavity—which is formed by a group of flat bones—or to provide a large area for the attachments of muscles as in the pelvic bones and the shoulder blade. Occasionally in the skull the " meat " of the sandwich is absorbed, leaving air spaces which are known as sinuses.

4. *Irregular Bones.*—Collectively these form a group of nondescript bones which cannot be allocated to the above 3 classes. The amount of compact bone is very small and most of the structure consists of spongy bone. The bones of the spine are irregular bones.

Mention must also be made of a certain variety of bone (e.g. the kneecap) which appears to have origin in a tendon. To such the name, sesamoid bone, is given. Bones of this type usually occur near a joint and their functions are the relief of pressure and the provision of facility in the movement of a joint.

The Nomenclature of Bones.—Certain terms are used in connection with bones, as mentioned below. A bone may contain hollows and elevations, canals, angles and outgrowths.

Eminences may be articular or non-articular. Examples of the former are the heads of the humerus and femur; the latter are demonstrated by tuberosities, trochanters, protuberances or processes, which are rough areas standing out clearly from the body of the bone and giving attachment to muscle fibres. A tubercle is a small nodule of bone. A spine is a sharp, pointed outgrowth. A ridge, crest or line is a bony elevation running along some prominent part of the bone.

Articular depressions are found in bones which receive the heads of other bones e.g. the glenoid cavity of the scapula and the acetabulum of the hip bone. Non-articular depressions are of many types. Various terms are used viz. fossa, a deep groove; pits; depressions; grooves; notches; furrows; fissures. A foramen is a canal or passage which perforates the bone. There are several other terms, but it is more satisfactory to explain each as it may occur.

CHAPTER 3

THE SKELETON—THE SKULL

THE CRANIAL BONES. THE INDIVIDUAL BONES OF THE SKULL. THE OCCIPITAL BONE. THE PARIETAL BONE. THE FRONTAL BONE. THE TEMPORAL BONE. THE ETHMOIDAL BONE. THE SPHENOIDAL BONE. THE MAXILLA. THE ZYGOMATIC BONE. THE NASAL BONE. THE LACRIMAL BONE. THE PALATINE BONE. THE INFERIOR NASAL CONCHA. THE VOMER. THE MANDIBLE. THE SKULL AS A WHOLE. SUTURES. FONTANELLES. THE ORBIT. THE NOSE. OTHER FOSSAE. THE MOUTH. THE TEETH.

THE skull is the portion of the skeletal system forming the bony part of the head and face. It is roughly egg-shaped with the broader portion at the back, and is poised on the top of the backbone, upon which it moves freely. There are 22 bones of the skull proper, but in association with the head there are also 3 ossicles in each ear, which are dealt with on pp. 279, 280, and the hyoid bone of the neck, which is described on p. 57.

Of the 22 bones in the skull, 21 are so closely bound together that only a thin furrow separates one from another, the edges of the bones being dovetailed into each other. The remaining bone is the lower jaw, which is so jointed to the skull that it moves on the upper jaw with a wide range, allowing the chewing of food. When the skull is dried the lower jaw becomes loose and is separated from the rest of the skull, but the other bones retain their positions and form a unit which must be carefully studied from all aspects.

The individual bones are either flat bones or irregular bones. Together they form the large and principal cavity of the head called the cranial cavity, which contains the brain, the lesser brain, various nervous tissue elements, membranes, blood vessels and nerves. The smaller cavities are 3 in number—two eye-sockets, or orbits, and the cavity of the nose. The compact layers, or tables, of the bones have a layer of spongy bone between them; this is termed the *diploë*. Here and there it will be found that the latter has been absorbed, leaving air spaces known as sinuses. The most important of these are connected with the nose, a fact which may enlighten us on the symptoms

of a cold in the head. The cavities of the ear, middle and internal, are also important; these are constructed out of the hollows and prominences of certain bony structures which are described later.

Before going on to the study of the individual bones, the nurse would be well advised to get a skeleton or to visit an anatomical museum regularly. Textbook descriptions are unsatisfactory at the best; sometimes they are confusing and inadequate. In this work an endeavour has been made to provide illustrations as clear and as true to the subject as possible and here and there may be found features mentioned which have been purposely left out of the text. But nothing beats a first-hand knowledge of osteology, obtained by handling and carefully examining the specimen and by checking the various facts which must be known.

The Cranial Bones.—There are 2 divisions of the bones of the skull: 1. the cranium or brain-case; 2. the anterior region or face. Below is given a list showing how the bones are distributed.

Bones of the Cranium

Occipital (base of the skull)	1
Parietal (crown)	2
Frontal (forehead)	1
Temporal (ear region)	2
Ethmoidal (between nasal and cranial cavities)	1
Sphenoidal (base of the brain and back of the orbit)	1
Total	8

Bones of the Face

Maxilla (upper jaw)	2
Zygomatic or Malar (cheek-bone)	2
Nasal	2
Lacrimal	2
Palatine (palate)	2
Inferior Nasal Concha or Turbinate	2
Vomer	1
Mandible (lower jaw)	1
Total	14

The Individual Bones of the Skull

There are various ways of studying the skull but it is most satisfactory first to take the bones individually. After we have become acquainted with the main features of each we can

reconstruct the skull and study it as a whole. In the following pages, therefore, we deal with the individual bones as they appear to us when disarticulated from the skull.

The Occipital Bone.—This bone forms the major portion of the back of the head at its lower part. It is somewhat like a large flat shell, rather irregular in outline, its saucer-like concavity corresponding to the curved surface of the back of the brain, which it covers and protects. It shows well marked angulation, and prominent at its base is an oval hole about the size of a penny, through which the spinal cord passes—the foramen magnum. Just in front of this foramen is a thick ridge of bone called the basi-occiput. On either side of the foramen magnum are two smooth, kidney-shaped areas; these are known as condyles; they are the areas of contact with the first bone of the spine —the atlas.

Looking at the external aspect of the bone, we note several well marked features (Fig. 23). The edges are jagged like a saw; they are known as serrated borders and fit the similar borders of other bones. A distinct knob or prominence is seen about the centre of the area above the foramen magnum. This is the external occipital protuberance. From the latter a median ridge runs to the foramen magnum—the median line; this divides the bone into 2 parts, each of which is further divided by 2 and sometimes 3 transverse lines—the nuchal lines. The surface of the bone shows roughened areas where muscles and ligaments are attached. In front of and also behind the condyles are little canals on either side. The first are known as the hypoglossal canals, through which pass the hypoglossal nerves; the lower are called the condyloid canals. A little tubercle—the pharyngeal tubercle—should be noted about the middle of the basi-occiput.

The inside of the bone is hollowed out like a large oyster shell, and we note that there are ridges and grooves corresponding to the structures of the brain in touch with the bone. A protuberance—the internal occipital protuberance—is the centre of a cross formed by 2 bony ridges, the eminentia cruciata. The main portion of the bone is thus divided into 4 areas, the 2 upper ones being occupied by the posterior lobes of the cerebrum and the 2 lower by the lobes of the cerebellum. Various brain membranes are attached to the crucial ridges. Other important landmarks are shown in the illustrations.

The Parietal Bone.—This bone forms the side and the roof of the skull, the two meeting in the middle line. Externally the bone is convex in all directions and forms a rough quadrilateral, with 3 of its sides markedly serrated. On the external surface, which is very smooth, there are 3 features viz. an eminence called the parietal tuberosity and 2 curved parallel lines giving

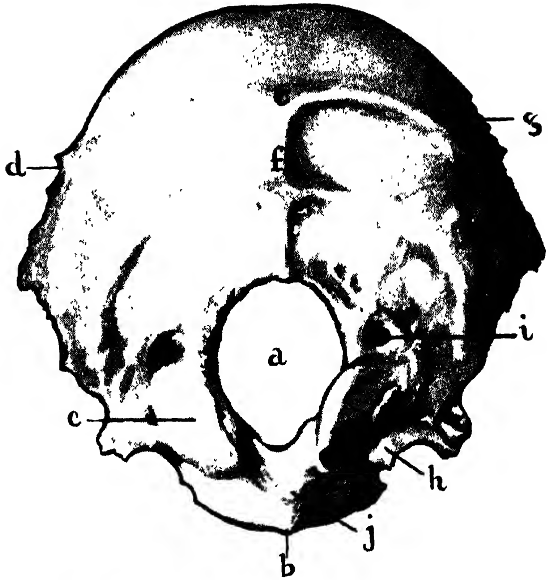


FIG. 23.—OCCIPITAL BONE. EXTERNAL ASPECT.

a, Foramen magnum. *b*, Basi-occiput. *c*, Condyle. *d*, Serrated border. *e*, External occipital protuberance. *f*, Median line. *g*, Superior nuchal line. *h*, Condyloid canal. *i*, Hypoglossal canal. *j*, Pharyngeal tubercle.

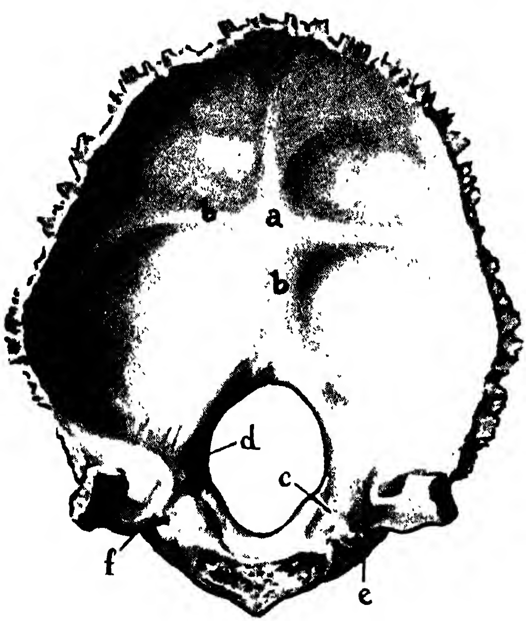


FIG. 24.—OCCIPITAL BONE. INTERNAL ASPECT.

a, Internal occipital protuberance. *b*, Eminentia cruciata. *c*, Jugular tubercle. *d*, Groove for part of transverse sinus. *e*, Hypoglossal canal. *f*, Jugular notch.

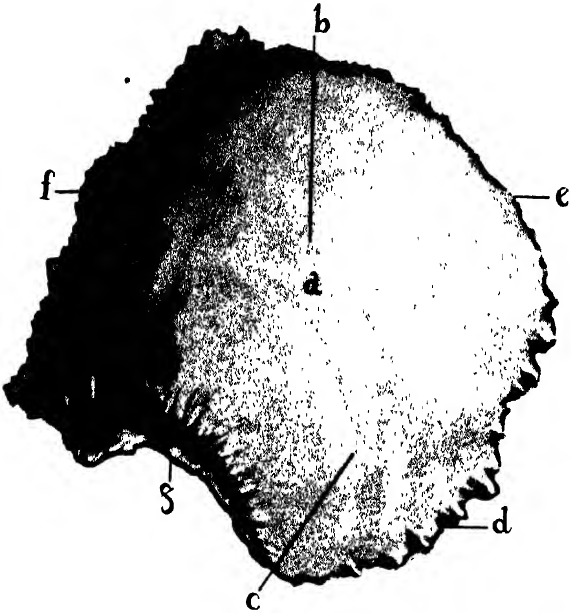


FIG. 25.—LEFT PARIETAL BONE. EXTERNAL ASPECT.

a, Parietal tuberosity. *b*, Superior temporal line. *c*, Inferior temporal line. *d*, Articulates with occipital bone. *e*, Articulates with opposite parietal bone. *f*, Articulates with frontal bone. *g*, Articulates with temporal bone.

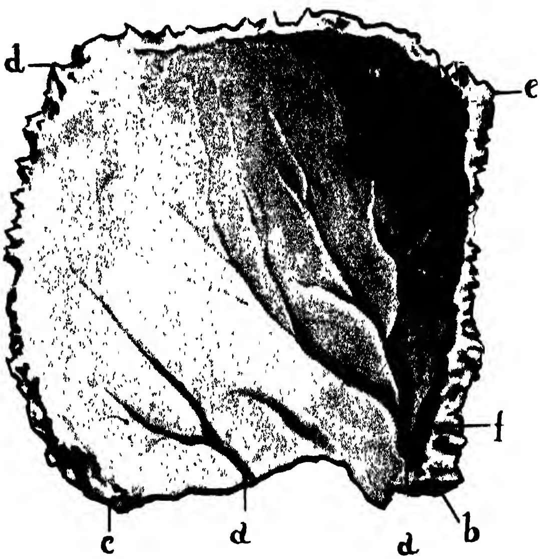


FIG. 26.—LEFT PARIETAL BONE. INTERNAL ASPECT.

a, Meningeal grooves. *b*, Sphenoidal angle. *c*, Mastoid angle. *d*, Occipital angle. *e*, Frontal angle. *f*, Groove for sinus.

origin to the temporal fascia and muscle. On the inside of the bone 2 areas are seen, grooved in a pattern resembling the branches of a tree; these are the grooves formed by the arteries supplying the membranes of the brain and are called the meningeal grooves. Several small hollows can also be made out; these correspond to the convolutions of the brain. The most prominent angle is the lower anterior angle known as the sphenoidal angle because it joins the sphenoidal bone. In front the parietal bone unites with the frontal bone, behind with the occipital bone (Figs. 25 and 26).

The Frontal Bone.—This bone forms the prominence of the forehead and its lower parts help to form the orbits. It is

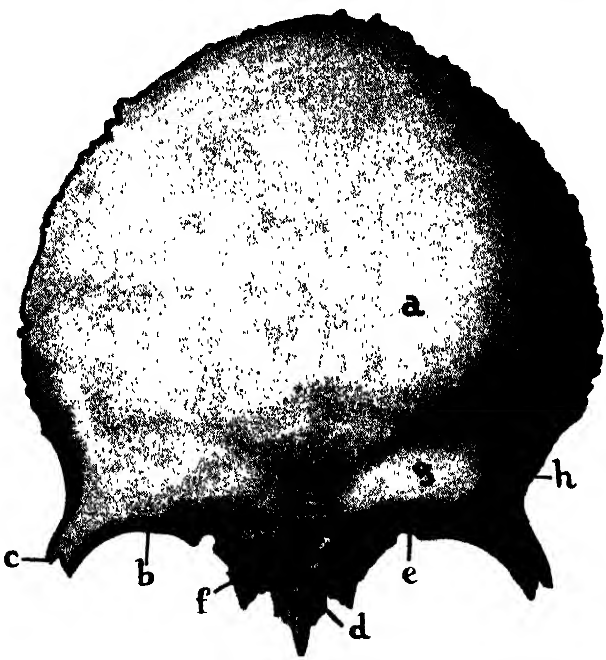


FIG. 27.—FRONTAL BONE. EXTERNAL ASPECT.

a, Frontal tuberosity. *b*, Supraorbital margin. *c*, Zygomatic process. *d*, Nasal notch. *e*, Supraorbital notch. *f*, Glabella. *g*, Superciliary ridge. *h*, Superior temporal line.

divided into a frontal part, 2 orbital parts and a nasal part (Figs. 27 and 28).

The Frontal Part.—This is the bony part of the forehead, the upper portion being part of the vault of the skull. Externally

the surface is convex in all directions but the convexity is most marked at a point about 1½ inches above the orbital border, where we find the frontal tuberosities. The lower part of the bone is represented by 2 rounded arches which form the supraorbital margin at the lateral limits of which are the zygomatic processes. Between these arches is a rough, angular area called

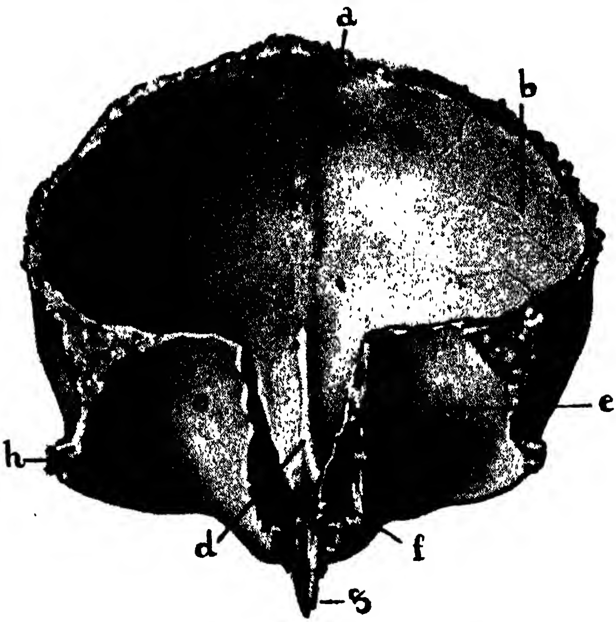


Fig. 28.—Frontal Bone. Internal Aspect.

a, Sagittal sulcus. *b*, Furrows for blood vessels. *c*, Orbital part. *d*, Ethmoidal notch. *e*, Ethmoidal air sinus. *f*, Frontal air sinus. *g*, Frontal spine. *h*, Zygomatic process.

the nasal notch. The supraorbital margin is grooved at the junction of its medial and middle two-thirds by a furrow—the supraorbital notch (sometimes a foramen) which allows the passage of the supraorbital nerve. Above the nasal notch is a prominence (which varies in individuals)—the glabella; from either side of it run out two low ridges called the superciliary ridges. The upper margins of the zygomatic processes are prolonged into a structure known as the superior temporal line. This line arches backwards and upwards, forming the boundary of the temple.

On the surface of the bone adjacent to the brain there is a

central groove called the sagittal sulcus, which is the boundary wall dividing 2 concave areas in which branching furrows are seen—the beds of the small blood vessels which supply the surface of the brain. Shallow depressions are also found, corresponding to the moulding of the bone over the nodular surface of the brain.

The Orbital Part.—This part of the bone roughly forms the roof of the eye socket. As we should naturally expect, the surface next to the eyeball is hollowed out and very smooth; indeed the bone looks as if it had been polished by fine emery paper. The superior surface is very similar to the rest of the inner aspect of the bone. When we look at the frontal bone from the inside the two medial portions of the orbital areas form a U-shaped structure enclosing a space known as the ethmoidal notch. The margins of the bones are like a honeycomb, the spaces thus formed being termed the ethmoidal air sinuses and the frontal air sinuses, both very important in the condition of cold in the head.

The Nasal Part.—From the nasal notch a little pyramid of bone points downwards like a wedge and is known as the nasal process and frontal spine. It forms the basis of the bridge of the nose and to it the nasal bones are fixed.

The edges of the frontal bone are jagged like a saw and like those of the occipital bone fit their neighbours intimately.

The Temporal Bone.—The temporal bone is divided into two main portions (Fig. 29)—a scale-like (or squamous) part and a hard stone-like part called the petrous portion. It is the bone which forms the section of skull round the ear and contains a central bony orifice, the opening of the ear canal—external auditory meatus. This is anterior to the mastoid process which is easily felt behind the ear in the living subject and contains important air cells associated with the ear. The squamous portion gives origin to the temporal muscle; its upper border unites with the parietal bone. Just above and in front of the ear canal is the root of the zygomatic process, which projects forward to join the malar bone and so to form the cheekbone. The petrous portion of the temporal bone is in the inside of the skull, forming a hard solid bulwark in front of the occipital bone, on the floor and side of the cranium. A very slender projection of bone, known as the styloid process, is seen pointing downwards between the mastoid process and the angle of the lower jaw. A plate of bone, the tympanic plate, forms the anterior half of the auditory meatus and a portion of the back wall; it merges with the petrous portion internally. Important structures contained in the temporal bone are the middle ear and the internal ear, and a cavity known as the tympanic antrum. On the medial and inferior aspects of the bone are many undulations, grooves and openings for important nerves and vessels, such as the occipital artery, the internal carotid artery and the internal jugular vein.

The Ethmoidal Bone.—This is rather a difficult bone to understand because it is hidden for the most part by other bones. It is small but very important, since it acts as a sort of keystone for the bony arch of the upper skull. It is cube-shaped, spongy

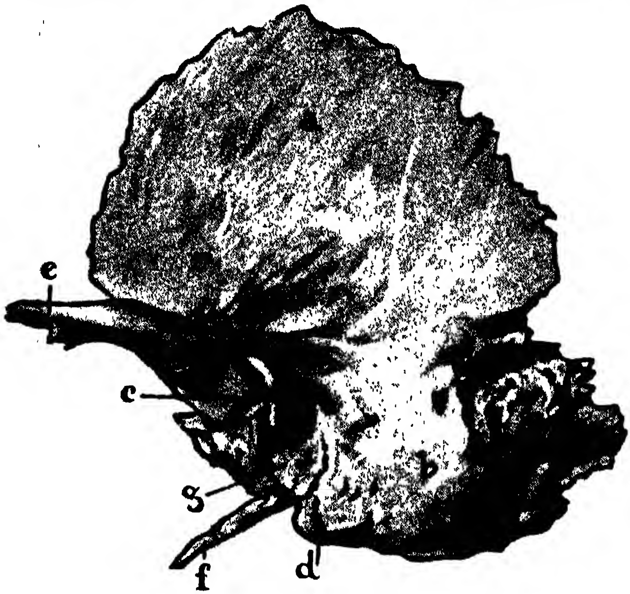


FIG. 29.—LEFT TEMPORAL BONE. EXTERNAL ASPECT.

a, Squamous part. *b*, Petrous part. *c*, External auditory meatus. *d*, Mastoid process. *e*, Zygomatic process. *f*, Styloid process. *g*, Tympanic plate.

and light, forming with other bones the medial wall of the orbit and the roof and sides of the nose. There are not any muscles attached to it.

The upper surface of the cube fits into the ethmoidal notch of the frontal bone and displays 2 main features: 1. a central elevated spur, which is named the crista galli because it is like a cock's comb and 2. on either side of the spur a hollowed depression containing numerous holes of different size and through which pass various nerves of smell to the nose; these originate in the olfactory bulbs which lie one on either side of the crista galli. The upper surface of the ethmoidal bone is often termed the cribriform plate (Fig. 30).

Passing vertically downwards and constituting the septum of the nose is a four-sided plate, its upper border forming the lower aspect of the crista galli. This portion, known as the lamina

perpendicularis, divides the nose into 2 chambers; its lower edge is thickened and slightly roughened at the areas of attachment of the nasal cartilage.

The ethmoidal bone, viewed from behind, has the outline of an insect. The head is the crista galli, the body the lamina and the wings are the large lateral masses or labyrinths. These are spongy, since they are divided into air sinuses by plates of bone. The lateral plate fits into the medial wall of the orbit and is

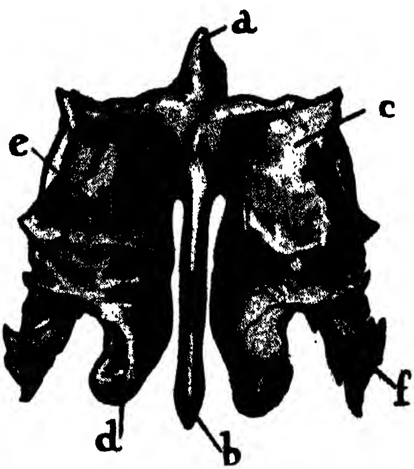


FIG. 30.—ETHMOIDAL BONE. POSTERIOR ASPECT.
a, Crista galli. *b*, Lamina perpendicularis. *c*, Labyrinth. *d*, Middle nasal concha. *e*, Superior nasal concha. *f*, Uncinate process.

called the *lamina papyracea*; it is smooth and roughly rectangular. The medial plate is divided by a deep fissure, the superior meatus, into the superior and middle concha respectively, these causing well marked bulges in the nasal canals. Below the middle concha and lateral to it can be seen a little bony tusk which is called the uncinate process and which points downwards and backwards. The whole surface of the bone is rather like the contents of a walnut, having a shrunken appearance; this is due to the numerous hollowed out cavities which form air chambers. The sphenoidal bone lies behind the ethmoidal bone.

The Sphenoidal Bone.—This bone is said to resemble a bat with its wings extended and it is not difficult to recognize when disarticulated from the skull, but since its name means "wedge-like," and since it is surrounded by other bones in the complete

skull its boundaries are not always easy to define. We recognize certain main divisions: a body, 2 sets of wings and 2 bony processes.

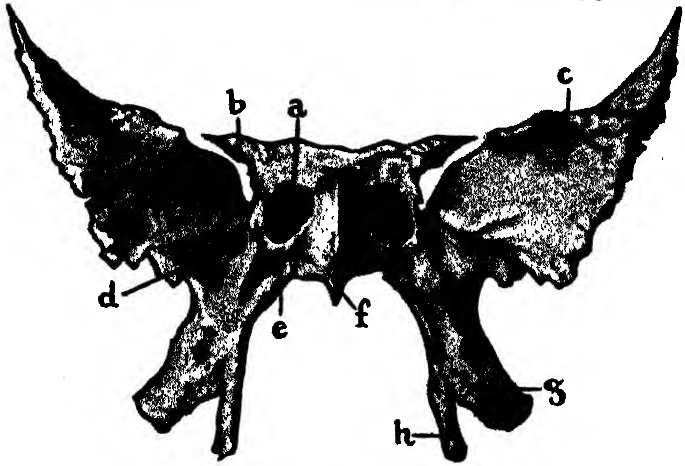


FIG. 31.—SPHENOIDAL BONE. ANTERIOR ASPECT.

a, Sphenoidal air sinus. *b*, Lesser wing. *c*, Greater wing. *d*, Foramen rotundum. *e*, Pterygoid canal. *f*, Rostrum. *g*, Pterygoid process. *h*, Hamulus.

The body of the sphenoidal bone unites behind with the basi-occipital. It is hollow and is divided by a thin wall of bone into

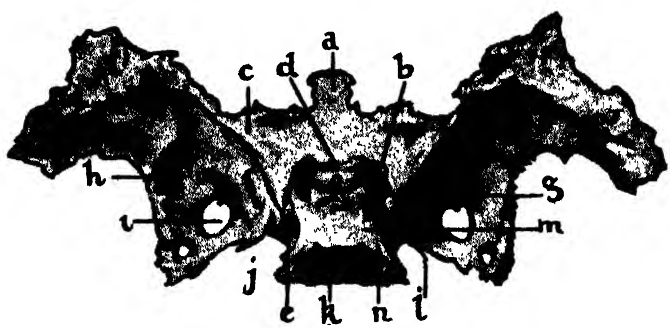


FIG. 32.—SPHENOIDAL BONE. SUPERIOR ASPECT

a, Ethmoidal spine. *b*, Optic foramen. *c*, Lesser wing. *d*, Optic groove. *e*, Anterior clinoid process. *f*, Tuberculum sellae. *g*, Middle clinoid process. *h*, Greater wing. *i*, Foramen ovale. *j*, Carotid sulcus. *k*, Dorsum sellae. *l*, Lingula. *m*, Hypophyseal fossa. *n*, Posterior clinoid process.

a right and a left half. In these spaces is air, the name given to the whole being the sphenoidal sinus. The lesser wings appear

to be set on the top of the greater wings, both pairs of which spread out on either side of the body. The superior surface of the bone forms an integral part of the floor of the brain cavity and has many important landmarks including a spine (which fits the ethmoidal bone) behind which the olfactory tracts run to the brain. Farther back is a deep groove, the *sulcus chiasmatis* which leads on either side to two important openings, the optic foramina. The posterior wall of this groove is formed by a ridge of bone which is rather like the pommel of a saddle; indeed the portion immediately behind it, which is a deep hollow, is called the Turkish saddle or *sella turcica*. The latter supports an important part of the brain called the hypophysis and the saddle is completed by the square plate of bone called the *dorsum sellae*. The illustrations (Figs. 31 and 32) show many points which can better be pictured than described. Note the small nodules called clinoid processes, three on each side, and called anterior, middle and posterior respectively. Note also that on either side of the seat of the saddle is a smooth broad groove, over which passes the internal carotid artery, one of the most important blood vessels in the body. On the upper portion of the front part of the body is a triangular crest which constitutes a small portion of the nasal septum. The openings into the sphenoidal air sinuses can be seen on either side of the crest. The under surface of the sphenoid shows a small spine called the rostrum.

The lesser wings are smooth on their upper surface because the brain lies on them; part of the roof of the orbital cavity is formed by the under surface but especially the upper boundary of the superior orbital fissure, the space through which travel from the brain many important blood vessels and nerves. A canal is formed by the two roots of the lesser wings on either side. This transmits the optic nerve and as mentioned above is called the optic foramen.

The greater wings lie beneath the small wings but occupy about four times the space; they turn up at the sides of the skull to form the beginning of the inner walls. The anterior portion forms the major part of the medial aspect of the orbit; the external portion of the upturned wing forms a triangular area of bone at the side of the skull in front of the temporal bone. Lastly there is a thin wedge visible just behind the upper jaw—the lateral pterygoid lamina, one of the pterygoid processes, which point down from the junction of the body and great wing and which form well marked spikes, one of which is called the hamulus.

The Maxilla.—The right and the left maxilla together form the upper jaw. They play an important part in the structure of the roof of the mouth, the floor and side of the nose and the floor

of the orbit. It is convenient to divide the bone into a body and 4 processes, termed respectively alveolar, frontal, palatine and zygomatic (Figs. 33 and 34).

The Body.—The main features of this portion are a fairly thick casing of bone forming a rough pyramid and a central air chamber of great importance called the maxillary air sinus or

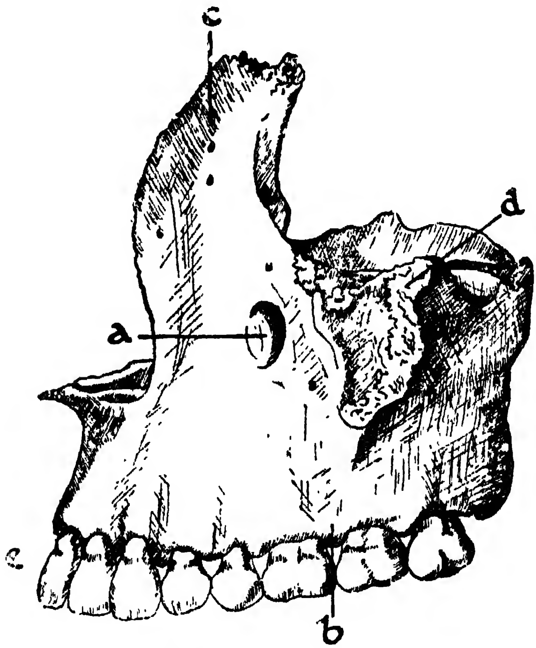


FIG. 33.—LEFT MAXILLA. EXTERNAL ASPECT.
a, Infraorbital foramen. *b*, Alveolar process. *c*. Frontal process. *d*, Zygomatic process. *e*, Tooth.

Antrum of Highmore. The front of the bone is somewhat bow-shaped and shows perpendicular ridges corresponding to the alveolar cavities of the upper teeth, that for the canine tooth being most prominent; if we follow this ridge upwards we come to the infraorbital foramen. All along the lower margin are the holes for the teeth. The medial part of the bone forms the lower boundary of the nasal cavity. The upper part constitutes the major portion of the floor of the orbit. Behind, the bone is rounded and constitutes the anterior wall of the infratemporal fossa. The maxillary air sinus is based on the nasal wall and has a large irregular opening into the nasal cavity.

The Alveolar Process.—This is really the lower margin of the body, perforated by the openings for the teeth and forming with its fellow a horseshoe-shaped ridge of thick bone, terminating on each side in a tuberosity. When teeth are extracted in life the alveolus bone is absorbed and leaves a smooth rounded edge. There are normally 8 apertures for teeth in each alveolus.

The Frontal Process.—This portion rises up like a spur from the

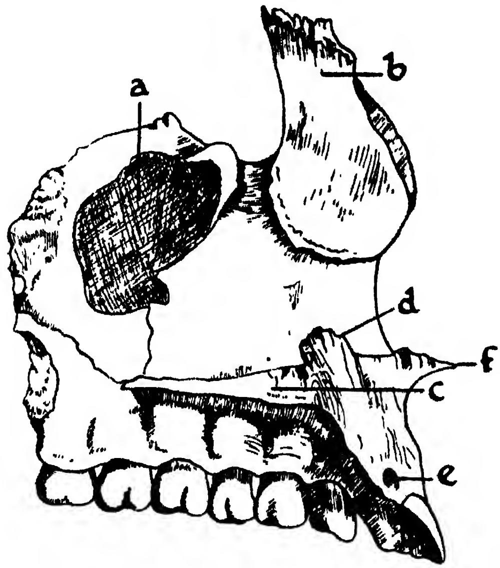


Fig. 34.—Left Maxilla. Internal Aspect.
a, Maxillary air sinus (Antrum of Highmore). *b*, Frontal process. *c*, Palatine process. *d*, Crest. *e*, Canal opening. *f*, Anterior nasal spine.

body, and takes part in the formation of the bony lateral wall of the nose behind the nasal bones and of the medial part of the rim of the orbit, next to the lacrimal bone. The small lacrimal tubercle should be noted.

The Palatine Process.—The palatine process is a shelf of bone which forms the floor of the nose on its upper surface, and the roof of the mouth on its under surface. The bone is strong and thick in front, but grows thinner as it passes backwards, forming three-quarters of the hard palate. The two proeesses when united form the well defined arch of the roof of the mouth and are so closely attached that they appear to be one bone, containing groups of small foramina, one in particular situated just behind the incisor teeth. These canals transmit various arteries

and nerves. The posterior part of the shelf is united to the palate bone. The medial portions are turned upwards and together form a crest to which the vomer is attached. At the anterior part of this crest is a spine of bone, jutting out like the prow of a ship above the teeth, the anterior nasal spine.

The Zygomatic Process.—Just below the rim of the orbit, a rough pyramidal mass of bone stands out from the body of the bone. This is the zygomatic process, a pillar of the prominent arch of the cheekbone, which it forms when united with the zygoma.

The Zygomatic Bone.—This is easily recognizable as the bony element which is the basis of the cheek. The bone is often referred to as the malar bone or as the zygoma. It forms part

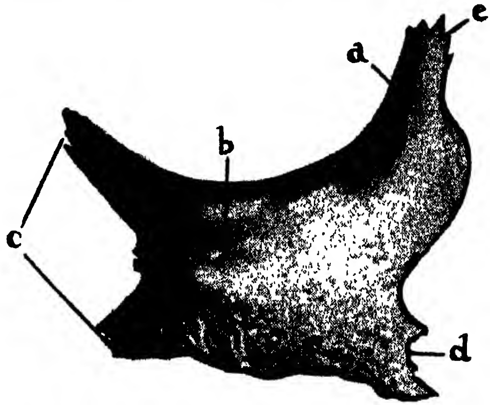


Fig. 35.—Left Zygomatic Bone. External Aspect.

a, Orbital surface. *b*, Foramen. *c*, Maxillary process. *d*, Temporal process. *e*, Frontal process.

of the floor and the side of the orbit and is roughly the keystone of the arch formed by the malar process of the temporal bone and the zygomatic process of the maxilla. The outline of the bone is more or less quadrilateral. The antero-superior surface is smooth, concave and rounded and shows usually 2 foramina; it forms part of the orbital margin (Fig. 35). At either end of the postero-superior surface are the rough areas attached to the frontal and temporal bones; below and in front there is the maxillary area.

The Nasal Bone.—The 2 nasal bones form the bridge of the nose; together they rest on the upper jawbone like a saddle. They are oblong and convex on the outside, with a groove on the inside for the anterior ethmoidal nerve. The upper border is rough, fitting in the nasal notch; the lower border gives origin

to the cartilage of the nose. The medial borders of these bones unite to form a crest which is part of the nasal septum.

The Lacrimal Bone.—This bone is so small, so delicate and so thin that it is often lost from a skull that has been used for teaching purposes. In size it is no bigger than the thumb nail. It fits into the mosaic of the orbit in front of the ethmoid bone and so forms part of the medial wall; it is roughly rectangular. Its main feature is a groove, just within the rim of the orbit, which contains the lacrimal sac, of much importance to the eye.

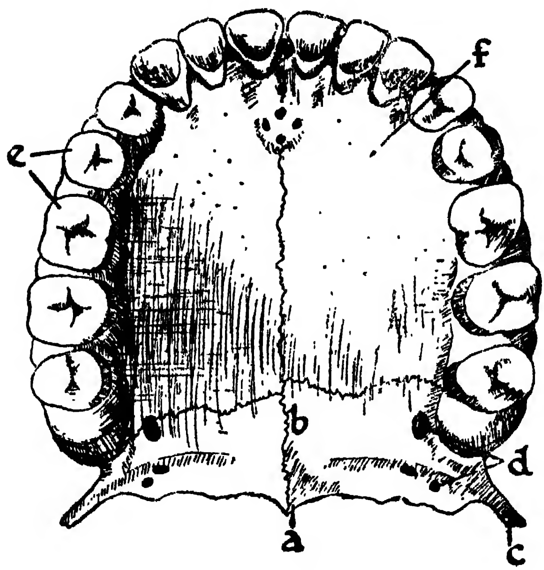


FIG. 36.—PALATE BONES AND ALVEOLAR ARCH.
a, Posterior nasal spine. *b*, Crest. *c*, Pyramidal process. *d*, Palatine foramina. *e*, Teeth. *f*, Palatine process of maxilla.

The Palatine Bone.—This bone is rough and irregular, shaped like the letter L. There are 3 well defined points called respectively the orbital, sphenoidal and pyramidal processes. The bone is fitted in between the sphenoid bone and the maxilla and fills in blanks in the floor and lateral wall of the nose, the floor of the orbit and the roof of the mouth. The lower part is roughly horizontal and constitutes one-quarter of the bony palate; it unites also with its fellow at a small prominence, the posterior nasal spine, to which the muscles of the uvula are fixed. The medial border forms half of a small crest, the continuation of the nasal crest of the maxillary bones. The vertical

part of the bone assists in the formation of the lower, the middle and the upper meatus of the nose; the three smooth areas can easily be made out as the bone is followed upwards from the horizontal portion. Part of the anterior portion of the palate bone is a constituent of the medial wall of the maxillary air sinus. The pyramidal process fits in between the maxillary tuberosity and the pterygoid plate of the sphenoid bone; it is sharply pointed. On the roof of the mouth it displays the 3 palatine foramina medial to the wisdom tooth. The orbital and sphenoidal processes are very small. The former contains an air sinus; the latter curves round slightly to form the sphenopalatine notch.

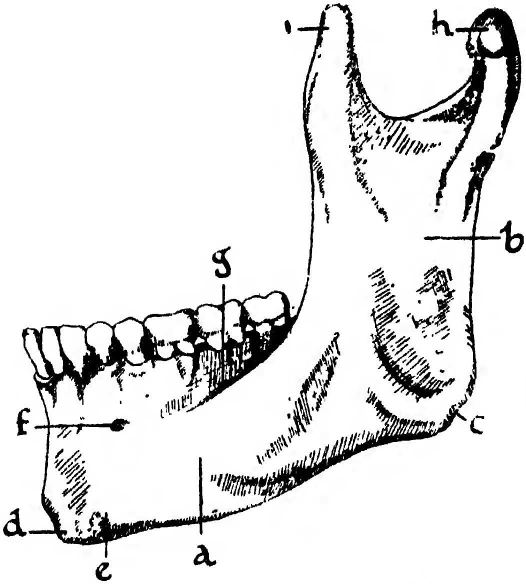
The Inferior Nasal Concha.—In appearance this small, slightly curved bone looks like a mussel shell cemented to the lower part of the lateral wall of the nose. The convex part looks towards the nasal canal and is perforated by several little holes; the reverse of the bone is scooped out; it shows flattened portions which are the articulation surfaces with the ethmoid, maxillary and lacrimal bones. The lower part of the bone is somewhat spongy.

The Vomer.—The meaning of this word is "ploughshare," and examination of the bone proves its apt terminology. The vomer forms part of the nasal septum; it articulates above with the ethmoidal bone and with the sphenoidal bone and ploughs its furrow, so to speak, on the upper jawbone and the palate bone. It has a free border behind, which forms the bony partition between the posterior nasal canals.

The Mandible.—The lower jawbone is single and is the biggest bone of the face. It can be divided roughly into two main portions, 1. the horizontal portion known as the body, and 2. the uprights, called the rami. The junction of these two is called the angle of the jaw.

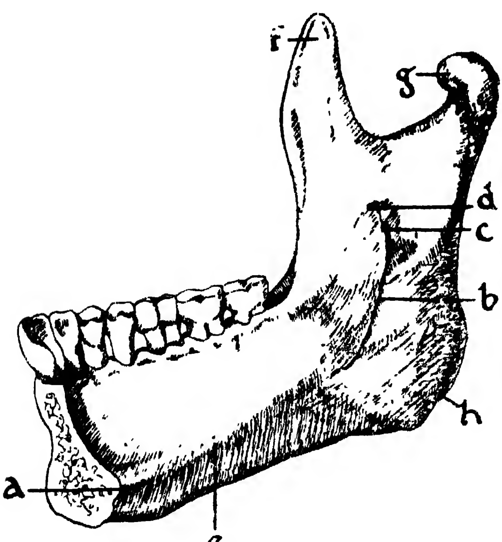
The body of the mandible is shaped like a narrow horseshoe and contains sockets for the 16 teeth. The point of the jaw is known as the mental protuberance and is bent forwards to form the prominence of the chin, a feature peculiar to man alone, although in the primitive races it is less marked; on either side of this eminence are two smaller elevations called the mental tubercles. A well marked opening is seen just below the second bicuspid tooth, the mental foramen; this allows the passage of important vessels and nerves. On the inside surface of the body at its middle is another protuberance known as the superior genial tubercle. There are rough lines and areas for the attachments of muscles.

The rami appear to be based on the angle of the jaw and at their upper ends are distinguished by two spikes with rounded ends. The one in front is sharper than the other; it is called the coronoid process and to it is fixed the temporal muscle which is of



a, Body. *b*, Ramus. *c*, Angle. *d*, Mental protuberance. *e*, Mental tubercle. *f*, Mental foramen. *g*, Oblique line. *h*, Condyle. *i*, Coronoid process.

FIG. 37.—LEFT MANDIBLE. EXTERNAL ASPECT.



a, Genial tubercle. *b*, Mylohyoid groove. *c*, Mandibular foramen. *d*, Lingula. *e*, Mylohyoid line. *f*, Coronoid process. *g*, Condyle. *h*, Angle of the jaw.

FIG. 38.—LEFT MANDIBLE. INTERNAL ASPECT.

great importance in the movement of the jaw. The posterior prominence terminates in a knob, the condyle, which forms part of the temporomandibular joint. Nearly the whole of the smooth external surface of the rami is occupied by the fibres of the masseter muscle, important in chewing. On the inside of the bone a groove is seen running down the middle of the ramus. Its upper part is an opening, the mandibular foramen, surrounded by a ledge of bone known as the lingula. From this the groove proper runs towards the lower border of the jaw and is called the mylohyoid groove. The mandibular canal is the tube through which the various vessels and nerves run to the teeth; it is buried in the body of the mandible (Figs. 37 and 38).

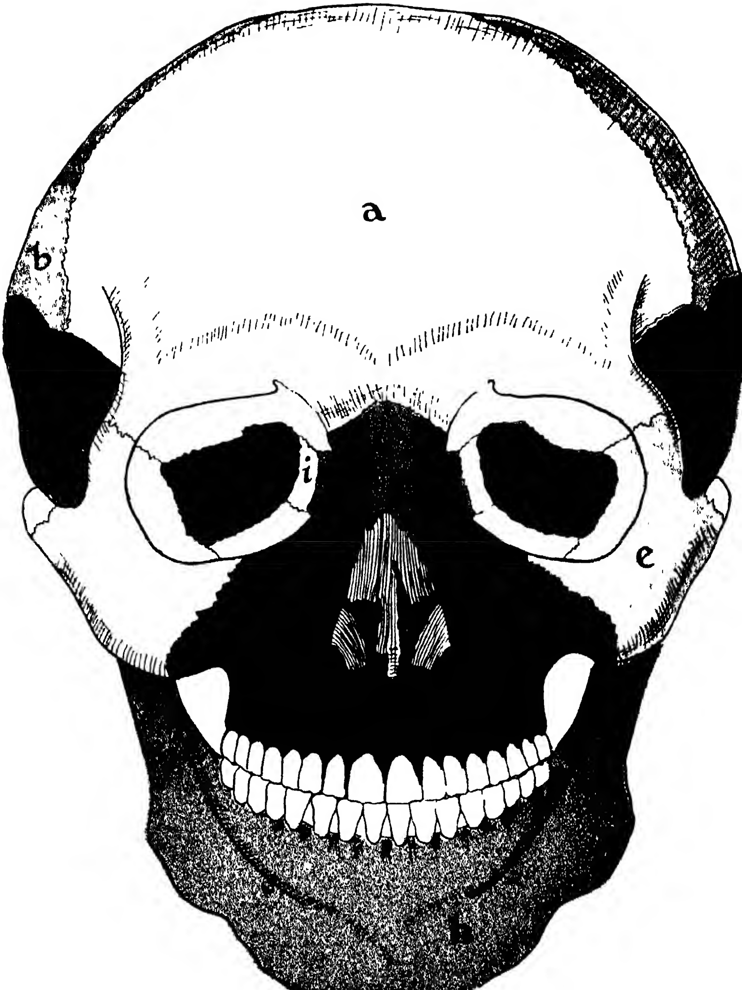
The Skull as a Whole

Having studied individually the various bones which compose the skull, we are faced with the problem of their relative positions in the skull. In order to make as simple as possible a rather complex task, two coloured illustrations are shown (Plates III and IV) in which the essential features are given and students are recommended to study these diagrams carefully, together with the individual bones already described.

Sutures.—It will be noted that the various bones fit into each other with saw-like teeth, forming jagged lines which are known as sutures. Prominent among the latter are the sagittal suture, which runs backwards over the crown of the head between the parietal bones; the coronal suture, between the frontal and parietal bones: the lambdoid suture, dividing the occipital from the parietal bones; the sphenofrontal suture; the squamosal suture, between the temporal and parietal bone.

Fontanelles.—In infancy, when the primary membrane has not completely turned into bone, certain spaces are left at the angles of the bones which are composed of membrane; in life pulsation can be felt in these areas, which are termed fontanelles. The most important one is the anterior fontanelle, a diamond-shaped space between the frontal bone and the parietal bones, and measuring about an inch and a half in length. This space gradually fills up until in a healthy child it is closed in the middle of the second year. The posterior fontanelle closes shortly after the child is born, and is not so easily recognized; it is situated at the point at which the lambdoid suture meets the sagittal suture.

The Orbit.—We have learned that the eye socket is made up of parts of bones which together form the smooth cavity easily recognized in the skull. Seven bones unite to make this cone-shaped cavity a sound protection for its delicate contents. The



THE SKULL. ANTERIOR ASPECT.

a, Frontal bone. *b*, Parietal bone. *c*, Temporal bone. *d*, Sphenoid bone. *e*, Zygomatic bone. *f*, Nasal bone. *g*, Maxilla. *h*, Mandible. *i*, Ethmoid bone. *j*, Lacrimal bone.

THE SKULL. LATERAL ASPECT.

a, Parietal bone. *b*, Temporal bone. *c*, Sphenoid bone. *d*, Frontal bone. *e*, Zygomatic bone. *f*, Lacrimal bone. *g*, Ethmoid bone. *h*, Nasal bone. i, Maxilla. *j*, Mandible. *k*, Occipital bone.

roof is formed by the orbital plate of the frontal bone and by the lesser wing of the sphenoidal. It contains the lacrimal fossa at its lateral angle, the site of the lacrimal gland. The floor shows portions of 3 bones viz. the orbital surfaces of the maxillary, malar and palate bones, with the infraorbital canal. The medial wall is made up of 4 plates, parts of the maxilla, lacrimal, ethmoidal and sphenoidal bones respectively. There is a well defined groove anteriorly for the lacrimal sac. The lateral wall consists of the orbital process of the malar bone and the greater wing of the sphenoid. In the orbit are 9 foramina, the chief of which are 1. the optic foramen situated at the apex, and the passageway for the optic nerve and the ophthalmic artery; 2. the superior orbital fissure, a narrow slit through which pass several important nerves, arteries and veins. At a point just outside the orbital rim, and so to speak at eleven o'clock on the dial, is a small canal or notch, the supraorbital notch. This is important as it transmits a nerve, the supraorbital nerve, which causes much pain when it is affected by neuritis.

The Nose.—Like the orbit, the nose is composed of several bones, being split by the septum nasi to form two nasal fossae. The entrance to the nose in front is called the anterior nares and the exit is called the posterior nares. Fourteen bones take part in the construction of this rather intricate structure. The septum, as we have already noted, is built up from the ethmoid plate and the vomer, and by the small crests of other bones. The roof is the cribriform plate of the ethmoid bone which allows the passage of the nerves of smell. The floor is formed by the maxilla and palate bone. The lateral wall is formed by the maxilla and by the ethmoid bones; from above downwards it presents in order the superior concha, the superior meatus, the middle concha, the middle meatus, the inferior concha and the inferior meatus.

Other Fossae.—There are 3 other distinct valleys or fossae of the skull, the temporal, the zygomatic and the sphenopalatine (Plates III and IV).

The Mouth.—Considering the bony cavity of the mouth only, we find that when the lower jaw is closed on the upper, the front of the cavity is formed by 2 rows of teeth, while the sides are formed by the inner aspects of the maxillae and mandible. The roof consists of the palatal process of the maxilla and of the palate bone.

The Teeth.—At the beginning of life, the child has no erupted teeth. At the age of 6 months, he "cuts" his first 2 lower central teeth, the incisors, and shortly afterwards 2 corresponding teeth on the upper jaw. The 4 lateral incisors may be cut at from 12 to 14 months; the first molars follow soon after,

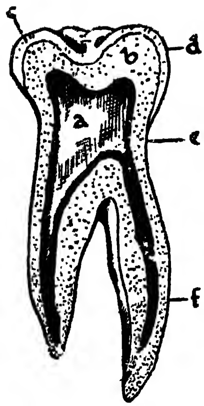


Fig. 39. — Longitudinal Section through a Molar Tooth.

a, Pulp cavity. *b*, Dentine. *c*, Enamel. *d*, Crown. *e*, Neck. *f*, Root.

and at the age of 18 months the child should have 4 canine teeth. Generally speaking, by the age of 2 years, a child should have his complete set of milk or temporary teeth, consisting of 10 teeth in each jaw i.e. 4 incisors, 2 canines, 4 molars.

At the age of 6 the child begins to lose his milk teeth, the incisors and first molars going first. Gradually the whole temporary set is replaced by the permanent teeth, which consist of 4 incisors, 2 canines, 4 bicuspids or premolars and 6 molars in each jaw. The complete set of teeth therefore numbers 32 teeth. The last teeth to appear, the wisdom teeth, erupt at any time between the ages of 17 and 21.

The structure of a tooth is shown in the diagram (Fig. 39). It will be noted that each tooth consists of a very hard shell of enamel, enclosing a substance which is akin to bone and which is called dentine. The tooth is divided into three parts: 1. the crown, which is above the gums; 2. the neck, which is at the gum margin; and 3. the root, which dips into the alveolar openings and which contains pulp, blood vessels and nerves.

CHAPTER 4

THE SKELETON—SPINAL COLUMN AND THORAX

THE VERTEBRAL COLUMN AS A WHOLE. THE INDIVIDUAL VERTEBRAE. THE CERVICAL VERTEBRAE. THE ATLAS. THE AXIS. THE VERTEBRA PROMINENS. THE THORACIC VERTEBRAE. THE LUMBAR VERTEBRAE. THE SACRUM. THE COCCYX. THE STERNUM. THE MANUBRIUM STERNI. THE GLADIOLUS. THE XIPHOID PROCESS. THE RIBS. A TYPICAL RIB. HOW TO RECOGNIZE CERTAIN RIBS. THE HYOID BONE.

It is advisable to deal with the vertebral column and the thorax together, because the spine forms a strong flexible pillar upon which is constructed, in its upper part, the barrel-like framework of bone formed by the ribs, the breast-bone (or sternum) and the cartilages associated with them. The thorax is inseparable from the part of the spine to which it belongs, therefore we must consider first the anatomy of the vertebral column and then study the ribs and sternum.

The Spinal Column

If we look at a thick bamboo cane we see that it is segmented, and that the boundaries of the segments are thickened whereas the body of the segment is somewhat waisted. The spinal column appears roughly to have a similar construction. Actually each segment of the spinal column consists of an individual bone, called a vertebra, moulded on a definite plan which is based on a body and an arch of bone. The individual vertebrae vary somewhat in size and shape according to the region to which they belong and it is possible to recognize each of the 26 bones; for example the vertebrae of the neck region are smaller, thinner and lighter than those of the lumbar region.

The Vertebral Column as a Whole.—Detached from all the other associated structures, the vertebral column somewhat resembles a caterpillar as the latter bends itself before moving forwards. The average length is 26 inches; and 4 curves are easily recognized from above downwards viz. the cervical curve bending forwards, the thoracic backwards, the lumbar forwards

FIG. 40.—THE SPINAL COLUMN. RIGHT LATERAL ASPECT.

a, Cervical vertebra. *b*, Thoracic vertebra. *c*, Lumbar vertebra. *d*, Sacrum. *e*, Coccyx. *f*, Atlas. *g*, Axis. *h*, Vertebra prominens. *i*, 1st thoracic vertebra. *j*, Intervertebral disc.

and the pelvic backwards. The column grows wider as we proceed from the head region to the pelvic region. Originally consisting of 33 bones, the spine contains at its termination the sacrum, formed by the fusion of 5 bones and the coccyx (the remnant of the tail), made up of 4 bones. These fused bones are referred to as fixed vertebrae in contradistinction to the others which are called movable vertebrae. Before passing on to a description of types of spinal bones we must consider how the spine acts. We know it is mobile, allowing the easy movements of bending and twisting to be carried out, yet there is great rigidity and support. This is due to the presence of numerous bands of fibres which extend the whole length of the column and bind together the segments. The spinal column is the protective canal of the spinal cord, probably the most vital structure of the body, and it is not to be wondered at that it is proof against all the stresses and strains of normal healthy activity. It should be noted that each vertebra is cushioned above and below. Between the bones are pads of stout elastic cartilage which act as buffers and diminish jolting or other shocks. These intervertebral discs are like the springs of a motor car and make for comfortable movement. In the skeleton, discs are absent since they cannot be preserved, but without them in life the spine would be well-nigh useless (Fig. 40).

The Individual Vertebrae.—All vertebrae present the following features. In front there is the body, consisting of thick spongy bone roughly heart-shaped with a convex border in front and a concavity behind. The sides of the bone are concave. The arch is situated behind the body and is made up of two short strong pillars called pedicles supporting a slightly angular plate of bone, with a prominent spine in its middle. These pedicles are notched above and below so as to form canals which are termed the intervertebral foramina; they allow the exit of the spinal nerves and the passage of vessels. The two lateral parts of the plate of bone mentioned above are

called the laminae, and the spine of bone between them is called the spinous process; the latter can be felt as a rounded knob when we pass our finger down the skin over the centre of the back and the whole series is obvious to the eye. The posterior part of the body, the 2 pedicles and the 2 laminae with their spinous process, surround an oval space which, when one bone is superimposed on another, forms a canal for the spinal cord. Two transverse processes of bone are seen jutting outwards, forming

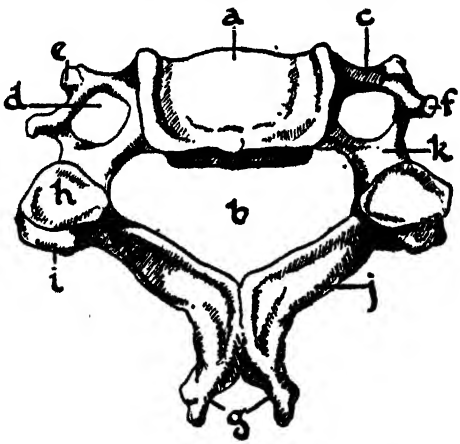


FIG. 41.—TYPICAL CERVICAL VERTEBRA. SUPERIOR ASPECT.

a, Body. *b*, Neural canal. *c*, Transverse process. *d*, Foramen. *e*, Anterior tubercle. *f*, Posterior tubercle. *g*, Spinous process. *h*, Superior articular process. *i*, Inferior articular process. *j*, Lamina. *k*, Pedicle.

wing-like outgrowths from the top of the pedicles; these are roughened for the attachment of ligaments and in the thoracic area small facets are present for the articulation of the ribs. In each vertebra there are 4 smooth articular processes inclined at an angle corresponding to the curve of the spine. They are like little bony buds from the junctions of the pedicles and the laminae, and they occur superiorly and inferiorly, acting as polished points of contact with similar outgrowths on neighbouring vertebrae and providing a series of very carefully adjusted joints. The spinous process may vary in character. Sometimes it is short and horizontal; at other times it is long and pointed and forms an acute angle with the body. Every vertebra shows a little foramen on its anterior and posterior aspects for the passage of blood vessels. Of the movable vertebrae—24 in all—3 groups are distinguished: the cervical or neck vertebrae number 7, the dorsal, thoracic or rib vertebra 12, and the lumbar 5 (see Figs. 40, 44, 45 and 46).

The Cervical Vertebrae.—The smallest bones of the vertebral column are found in the neck region. They are characterized by a relative diminution of the size of the body (which is somewhat flattened) as compared with the neural canal which is roughly triangular. Two distinguishing features are evident. First the spinous processes appear to be split (bifid) and thus form 2 small nodules; secondly the transverse processes are bored by a foramen which is part of the canal for the vertebral

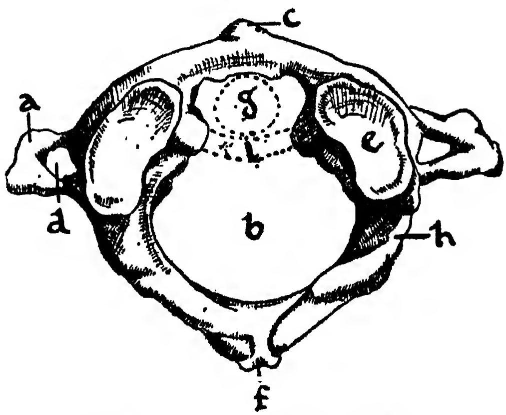


FIG. 42.—ATLAS. SUPERIOR ASPECT.
a, Transverse process. *b*, Neural canal. *c*, Anterior tubercle. *d*, Foramen. *e*, Superior articular surface. *f*, Spinous process. *g*, Outline of section of dens. *h*, Lamina. *i*, Outline of ligament.

artery. Two tubercles of bone flank this canal, the anterior and posterior tubercles. The articular facets look backwards and upwards (Fig. 41).

The Atlas.—This is the first bone of the column, articulating with the skull at the condyles, on either side of the foramen magnum. It may be regarded as a ring of bone supporting the head and allowing nodding movements to take place. The centrum of bone is almost non-existent, the spine is very minute and the articular processes are large and prominent (Fig. 42).

The Axis.—The most prominent feature of this bone (the 2nd of the vertebral column) is the odontoid process, known also as the dens (tooth) which projects up like a small peg into the anterior portion of the spinal foramen of the atlas above, the 2 bones thus forming an important unit allowing for both nodding and pivoting of the skull. The odontoid process is kept in position by the important transverse ligaments. The transverse processes are not bifid (Fig. 43).

The Vertebra Prominens.—The 3rd, 4th, 5th and 6th vertebrae

show no marked deviations from the normal type. These vertebrae tend to become more compact and larger in size as we approach the lower end. The 7th and last cervical vertebra has one distinctive feature, however. The spinous process is not cloven or bifid; it is rather longer than the other cervical spinous processes and has a prominent nodule at its tip known as the tubercle of the spine; this can easily be felt when we pass our fingers down the lower part of the middle of the neck region. For this reason, the bone is called the *vertebra prominens* and is an important landmark in the surface anatomy of the neck. The transverse foramen may be absent; in any case it is very small and rarely is traversed by the vertebral artery (Fig. 44).

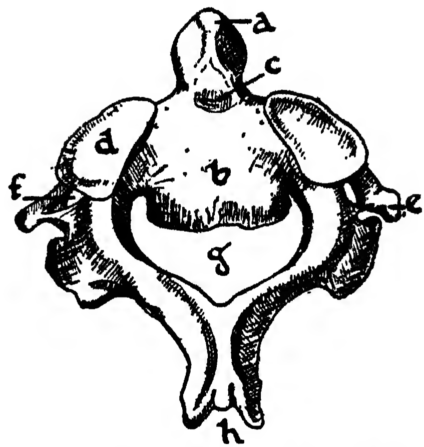


Fig. 43.—Axis. Posterosuperior Aspect.

a, Dens. *b*, Body. *c*, Groove for ligament. *d*, Superior articular surface. *e*, Transverse process. *f*, Foramen. *g*, Neural canal. *h*, Spinous process.

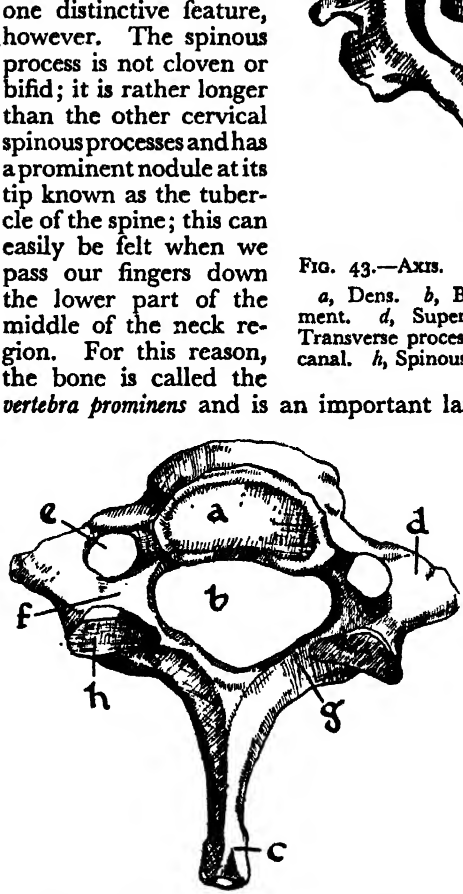


Fig. 44.—Vertebra Prominens. Upper View.

a, Body. *b*, Neural canal. *c*, Spinous process. *d*, Transverse process. *e*, Foramen. *f*, Pedicle. *g*, Lamina. *h*, Superior articular surface.

The Thoracic Vertebrae.—The distinguishing point about the thoracic or dorsal vertebrae is that on either side of the body are facets for articulation with a rib. The position of these articular surfaces varies according to the bone under consideration. Thus the 1st dorsal vertebra has 1½ facets;

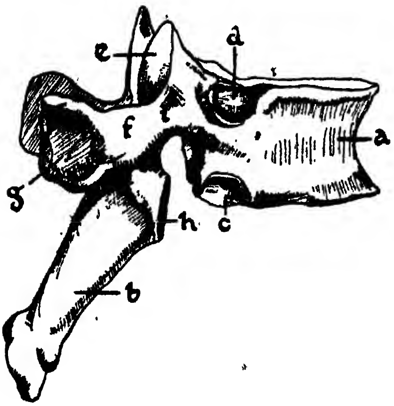


FIG. 45.—TYPICAL THORACIC VERTEBRA. RIGHT LATERAL ASPECT.

a, Body. *b*, Spinous process. *c*, Inferior costal facet. *d*, Superior costal facet. *e*, Superior articular process. *f*, Transverse process. *g*, Costal facet of transverse process. *h*, Inferior articular process. *i*, Pedicle.

the 2nd–8th have each 2 half-facets; the 9th has half a facet; the 10th, 11th and 12th have 1 facet. In addition to this there are articular plates on the transverse processes of the first 10 vertebrae, but not of the last two. The facets on the bodies correspond to the areas at which the heads of the ribs articulate with the spine; the facets on the transverse processes are for the tubercles of the ribs. Generally speaking the body of a typical dorsal vertebra is heart-shaped, or roughly cubical, but the lower dorsal vertebrae are very difficult to distinguish from the lumbar vertebrae. The spines are pointed backwards and downwards and tend to overlap each other. The transverse processes are very strong (Fig. 45).

The Lumbar Vertebrae.—The 5 lumbar vertebrae are wider from side to side than in the anteroposterior direction; the body of the bone is also thicker in front and is kidney-shaped in section. The spine is nearly horizontal, is shaped like a hatchet and has rather a blunt and thickened edge. The transverse processes are in front of the articular processes and seem to take the place of the ribs; they incline slightly upwards and have retained certain of the slenderness and proportions of the ribs above. The

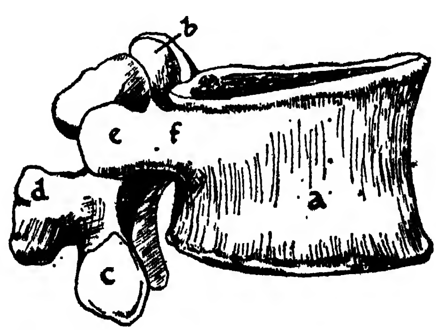


FIG. 46.—FIFTH LUMBAR VERTEBRA. RIGHT LATERAL ASPECT.

a, Body. *b*, Superior articular facet. *c*, Inferior articular facet. *d*, Spinous process *e*, Transverse process. *f*, Pedicle.

lumbar vertebrae do not have any foramina or rib facets. The 5th lumbar vertebra is especially deep in front, thus taking part in the prominence of the spine at the lumbosacral joint. Its transverse processes are much thicker and shorter than those above it (Fig. 46).

The Sacrum.—Formed by the fusion of 5 vertebral elements, the sacrum (sacred bone) is a triangular structure, which looks

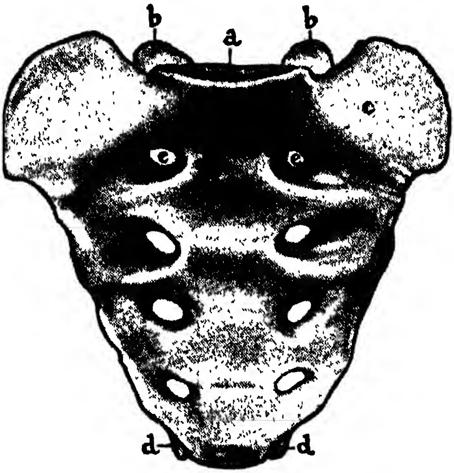


FIG. 47.—SACRUM. ANTERIOR ASPECT.

a, Promontory. *b*, Articular processes for the 5th lumbar vertebra. *c*, Ala. *d*, Cornua. *e*, Sacral foramina.

as if it had been scooped out in front. It is firmly wedged, with its base uppermost, between the 2 *ossa innominata* of the pelvis, while it articulates above with the last lumbar vertebra and below with the coccyx. The central portion corresponds to the mass formed by the fusion of the 5 bodies of sacral "vertebrae." On either side is the lateral mass, or ala, consisting of the bony remnants of what presumably have been transverse processes and pelvic ribs. Behind, the neural canal is continued as the sacral canal, which contains the openings of the sacral foramina and which ends low down on the back of the bone owing to deficiency of its posterior wall. Knowing the composition of the sacrum we can appreciate the presence on the anterior surface of 4 ridges and 8 foramina and a similar number of grooves for the

anterior sacral nerves. At the point of junction with the last lumbar vertebra there is a well marked promontory which juts out towards the pelvis. Rudimentary tubercles form the median sacral crest on the posterior surface, on each side of which is a groove. A little tubercle of bone at the tip of the sacrum on either side is known as the cornu; this is a remnant of the articular process (Fig. 47).

FIG. 48.—THE COCCYX. ANTERIOR ASPECT.

a, Cornua. *b*, Rudimentary transverse process. *c*, Articulates with sacrum.

The Coccyx.—The coccyx is all that is left to man of his tail, and it retains just enough of its vertebral characteristics to preserve its division into 4 (and sometimes 5) little nodular areas, blended into 1 bone attached to the point of the sacrum and of triangular shape. This small bone is said to resemble the cuckoo's beak, hence the term, coccyx, the Greek word for cuckoo. It is rough behind, due to muscle attachment, and smooth in front. Note the 2 cornua, forming with the sacral cornua a canal for the 5th sacral nerve (Fig. 48).

The Thorax

Various authorities have likened the thorax to a cage, to a cone and to a barrel, but none of these describes the framework accurately; the cavity is formed by a basic ridge—the dorsal vertebral column—from which on either side spring 12 curved and more or less parallel stays called the ribs. The latter are completed by the costal cartilages and sternum, so that if a section of the thorax were taken about its middle the outline would be kidney-shaped. The thorax is an unusual cavity; it is narrow at its upper region and wide at its base, and the variable curving of the ribs entails a constantly changing outline at successive levels. In addition to this the thorax is longer behind than in front and flattened from before backwards. The floor of the thorax is formed by the powerful diaphragm muscle.

In this cavity many important structures are contained which need only be mentioned at this point. First there is the heart, almost central, and on either side the lungs, occupying most of the cavity; the respiratory tubes, many important nerves, the gullet and various vessels and glands are all described in detail later on. For the present it is essential to consider the bony portion only and to study the sternum, ribs and costal cartilages.

The Sternum.—Commonly called the breast-bone, this bone

is made up of 3 parts, although there are 6 ossification centres, and is about 7 inches long. It is a flat bone, pointed at the tip. It is best to take its 3 portions in succession (Fig. 49).

The Manubrium Sterni.—As its Latin name implies, this part of the sternum represents the handle of the sword. It is triangular with the angles snipped off; both surfaces are smooth. The upper border is thick and is notched in the centre by a depression known as the inter-clavicular, suprasternal or jugular notch. On either side of the notch are areas for articulation with the clavicle (collar-bone) and lower down are similar areas for the first ribs. Still lower down at the tip of the handle are 2 half-facets for the second ribs. The junction of the manubrium and the next part —the gladiolus or sword—is padded by a thin piece of cartilage and is more prominent than the surrounding bone. It is a well known landmark in surface anatomy, known as the sternal angle or *angulus Ludovici*, indicating the level of the second rib.

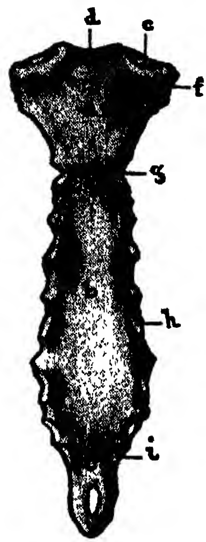


FIG. 49.—THE STERNUM. ANTERIOR ASPECT.

a, Manubrium sterni. *b*, Gladiolus. *c*, Xiphoid process. *d*, Jugular notch. *e*, Articulates with clavicle. *f*, Articulates with 1st rib. *g*, Angulus Ludovici. *h*, Articulates with cartilage of 4th rib. *i*, Articulates with cartilage of 7th rib.

The Gladiolus.—The blade of the sword is also known as the body of the sternum. It is narrow, flat and smooth, articulating with the cartilages of the 2nd–7th ribs on either side at fairly regular intervals. Above it articulates with the manubrium; below with the ensiform process.

The Xiphoid Process.—Other names are ensiform cartilage, ensiform appendix and xiphoid bone; it is the point of the sword. In young people this part is cartilaginous; bony deposits are found in the aged. In structure, the xiphoid process consists of cancellous tissue covered by 2 thin layers of compact bone. At the upper border on either side are facets for half of the 7th-rib cartilages. The shape of the xiphoid varies considerably; sometimes it is bifid, at other times curved or deflected. Its tip is associated with the fibres of certain important muscles. In front is attached a small tag of the rectus muscle of the abdomen as well as the costal ligament. Behind it gives attachment to a part of the diaphragm muscle. The lateral borders hold the aponeurosis of the abdominal muscles.

The Ribs.—The ribs constitute the principal part of the thoracic wall; they are like the hoops of a barrel but the lower

ones are not complete. In all there are 12 pairs of ribs, of which 7, the true ribs, articulate direct by means of their cartilages with the sternum and 5, the false ribs, are not connected with the sternum. The upper 3 of the false ribs, however, join the cartilage of the 7th rib by a sort of overlapping process; the lowest 2 ribs are quite free, and are called the floating ribs. In some cases an extra rib is found in the neck; this is referred to as cervical rib and gives rise to an interesting and important surgical condition.

A Typical Rib.—The 5th or 6th rib may be studied as a typical example of the variety of bone. Ribs are said to be long bones but they have no canal proper; they have a shell of compact bone

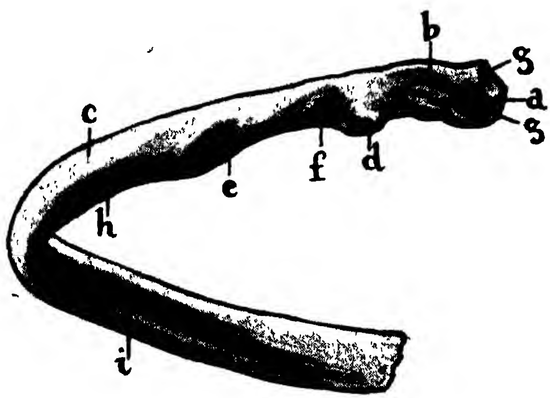


FIG. 50.—RIB FROM THE LEFT SIDE. POSTERIOR ASPECT.

a, Head. *b*, Neck. *c*, Shaft. *d*, Articular part of tubercle. *e*, Non-articular part of tubercle. *f*, Ridge. *g*, Facets for articulation with vertebra. *h*, Angle. *i*, Costal groove.

enclosing spongy bone, which is full of red marrow. Each rib presents a head, a neck and a shaft and is curved rather like an exaggerated letter J. The head is the end which is in association with the vertebrae. When the vertebral column was discussed, we remarked that the facets for the ribs were divided between the adjacent vertebrae; 2 facets on the ribs fit these. A small ridge intervenes and gives attachment to connecting strands with the intervertebral cartilage. The neck is about an inch long, smooth in front and roughened on its upper border by the crest for the superior costotransverse ligament. A tuberosity is situated just at the junction of the neck with the shaft and has a facet which articulates with the transverse process of the vertebra; immediately below it there is a non-articular tubercle roughened for the attachment of its special ligament. Just in front of the

tuberosity is the angle of the rib—the point at which the bending is most acute—and then the shaft continues, somewhat twisted in its axis. The inner surface is naturally concave; the upper border is rounded and smooth but the lower border is grooved by the channels of the blood vessels and nerves. At the sternal end of the rib is a small oval depression for the adjustment of the cartilage joining the rib to the sternum. The ribs are separated by the intercostal spaces, which contain the intercostal muscles. These spaces vary in size depending upon the individual; it must also be remembered that the ribs point downwards from the spine, then tend to rise to a slightly higher level. The sternal ends are more freely mobile in order to meet the demands of various types of breathing (Fig. 50).

How to recognize Certain Ribs.—The first rib is short and broad; it is almost like the letter U. There is only 1 facet on the head. The upper surface is relatively broad and flat and shows 2 well marked grooves on either side of a tubercle called the scalene tubercle; 1 groove is for the subclavian artery, the other for the subclavian vein. The 2nd rib takes much the same course as the first, but with a wider circumference; the angle occurs very near to the tuberosity and the upper surface is rough owing to areas of muscle attachments. The 10th rib has only 1 facet, the 11th 1 facet but neither tuberosity nor neck, the 12th no angle and 1 facet only.

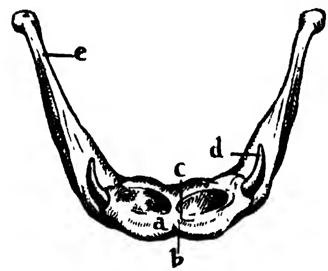


FIG. 51.—THE HYOID BONE. ANTERO-SUPERIOR ASPECT.

a, Body. *b*, Tubercle. *c*, Crucial ridge. *d*, Lesser cornu. *e*, Greater cornu.

The Hyoid Bone

This bone is noted chiefly because it is a bone of contention. Some authorities regard it as a bone of the head, others of the neck and others as an entirely distinctive type of bone, since it does not articulate with any other bone of the body. It is U-shaped, with a thickened body and 4 cornua—2 greater and 2 lesser. Numerous muscles and ligaments are connected with it and it supports the tongue. It gives attachment among others to the mylohyoid, omohyoid, stylohyoid, thyrohyoid and geniohyoid muscles. The bone is suspended from the styloid processes of the temporal bones by a ligament called the stylohyoid ligament. At the centre of the body is a tubercle from which a crucial ridge runs (Fig. 51).

CHAPTER 5

THE SKELETON—THE SHOULDER GIRDLE AND UPPER EXTREMITY

THE CLAVICLE. THE SCAPULA. THE HUMERUS. THE RADIUS. THE ULNA. THE CARPUS. THE METACARPUS. THE PHALANGES.

THE appendicular skeleton is represented in the upper regions by the arms and, since one arm is practically the duplicate of the other, it will be convenient to study the right arm only, any differences in the left being mentioned in passing. The shoulder girdle consists of 2 bones, the clavicle and the scapula, while the arm is made up of a single upper bone, the humerus, and 2 lower bones, the radius and the ulna. The hand and wrist contain from above downwards a closely packed group of bones called the carpus, a row of bones called the metacarpus and 3 rows of bones called the phalanges (Fig. 20).

The Clavicle

Known also as the key-bone and collar-bone, this bone is one of the most important in the body since it is frequently broken in accidents and it forms a vital part of the arch or girdle from which the arm depends. The collar-bone is shaped like the italic letter *f* and appears to be set on the apex of the thorax, jutting out like a beam to the point of the shoulder and acting as a " coat-hanger " for the muscles of the upper part of the thorax. It looks like a long bone but is actually a short bone, since it has no medullary canal. Its double curve gives it resistance and it is the most elastic bone of the body. The medial two-thirds are more circular than the lateral third, which is considerably flattened; roughly the bone is convex at its medial two-thirds and concave at its lateral third. The medial or sternal end articulates with the upper end of the sternum at the clavicular notch; the articulation is known as the sternoclavicular joint. There is a shallow hollow also on the inferior surface for articulation with the 1st costal cartilage. There is an upper border which ceases when the concave portion begins; it has a rough area for the sterno-cleido-mastoid muscle. The under surface of

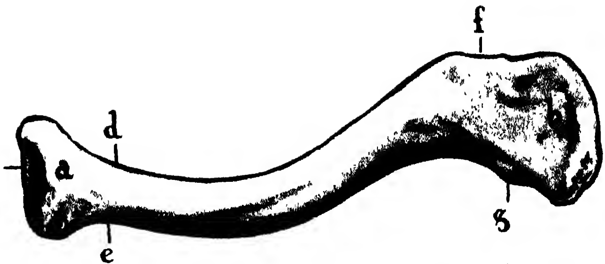


FIG. 52.—THE LEFT CLAVICLE. SUPERIOR ASPECT.

a, Sternal end. *b*, Acromial end. *c*, Articulates with the sternum. *d*, Attachment of sterno-cleido-mastoid. *e*, Attachment of pectoralis major. *f*, Attachment of trapezius. *g*, Deltoid tubercle.

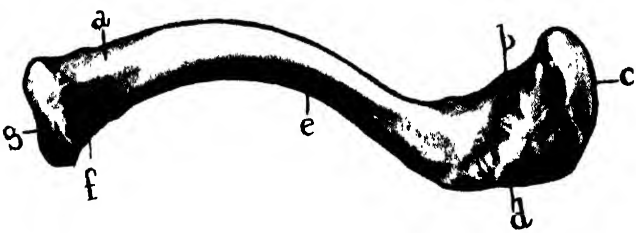


FIG. 53.—THE LEFT CLAVICLE. INFERIOR ASPECT.

a, Attachment of pectoralis major. *b*, Attachment of deltoid. *c*, Articulates with acromion process. *d*, Attachment of trapezius. *e*, Attachment of subclavius. *f*, Attachment of sternohyoid. *g*, Articulates with 1st rib.

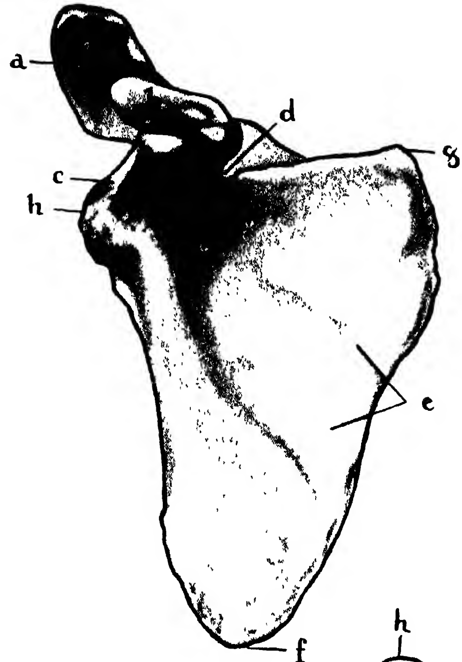


FIG. 54.—THE RIGHT SCAPULA. VENTRAL ASPECT.

a, Acromion process. *b*, Coracoid process. *c*, Glenoid cavity. *d*, Suprascapular notch. *e*, Ridges. *f*, Inferior angle. *g*, Medial angle. *h*, Lateral angle.

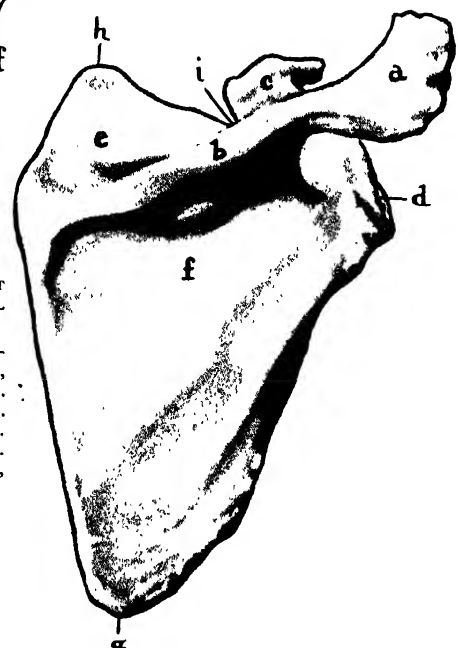


FIG 55.—THE RIGHT SCAPULA. DORSAL ASPECT.

a, Acromion process. *b*, Spine. *c*, Coracoid process. *d*, Glenoid cavity. *e*, Supraspinous fossa. *f*, Infraspinous fossa. *g*, Inferior angle. *h*, Medial angle.

the bone has several grooves and tubercles for muscles and ligaments, with a specially marked groove for the subclavius muscle. Here also is the nutrient foramen for the blood supply. In front the bone in its convex part is rough for the attachment of the great muscle of the chest, the pectoralis major; the concave part is marked by the deltoid tubercle and a rough area, both for the deltoid muscle. On the posterior aspect, the lateral third is rough for the attachment of the trapezius muscle. The lateral end of the bone is flattened, and is in close association with the acromion process of the scapula, therefore it is known as the acromial end. The clavicle is close to the skin and is easily seen and felt in its entire length at the base of the neck (Figs. 52 and 53).

The Scapula

The scapula, or shoulder-blade, is a very flat triangular bone forming the basis of the prominence at the back of the shoulder. It usually lies flat on an area bounded by the 2nd and 7th ribs. Its main outgrowth, the acromion process, combines with the clavicle in forming a type of " bowsprit " which keeps the point of the shoulder, and consequently the arm, out from the chest. The bone is so thin that in some places it is transparent. The features of the anterior surface are ridges which give origin to the subscapularis muscle and it should be noted that the bone is slightly hollowed for the fleshy part of that muscle. There is also a roughening of the vertebral border along which the serratus magnus muscle is attached. On the posterior or dorsal surface the outstanding structure is the spine, which passes obliquely outwards to the shoulder, dividing the bone into 2 main areas known as the supraspinous fossa and the infraspinous fossa. In the former lies the supraspinatus muscle; in the latter there is the infraspinatus muscle. Note that the base of the spinous process is smooth for the passage of fibres of the trapezius muscle of the back. At the outer margin there is a roughness for several other muscles. The spine gradually elevates itself from the body of the bone until it becomes a sort of handle, flattened and prominent—the acromion process. This process articulates with the acromial portion of the clavicle and forms an awning over the glenoid cavity; the deltoid and trapezius muscles are attached to it. Another projection, very much smaller, hooks over from the upper border of the bone and overhangs the glenoid cavity; this is called the " crow's beak " or coracoid process; from its tip there arises the coracobrachialis muscle and the tendon of the short head of the biceps muscle; the coraco-acromial ligament is attached to the outer border; the pectoralis minor muscle is inserted into the front of the coracoid process;

at its root are the attachments for the conoid and trapezoid ligaments. The upper border of the bone presents a sharp indentation, the suprascapular notch, which conveys important vessels and nerves. Three angles are recognized, the medial, at the junction of the upper and vertebral (or medial) borders, the inferior, at the point at which the vertebral border meets the axillary border and the lateral which is also known as the head of the scapula. Here we find a circular, hollowed out, smooth plate of bone, the glenoid cavity, which receives the head of the humerus and constitutes the socket of a ball-and-socket joint (Figs. 54 and 55). Other important muscular attachments are as follows. On the upper border is the inferior belly of the omohyoid muscle; on the vertebral border above is the levator anguli scapulae muscle and lower down the rhomboid muscles, minor and major; on the axillary border are the teres minor and teres major muscles; at the inferior angle is the attachment of the latissimus dorsi muscle.

The Humerus

This bone is the central foundation of the upper arm round which muscles are grouped to give the characteristic outline. The average length is 12 inches; it is the longest and largest bone of the whole arm and is a true " long " bone, presenting 2 extremities and a shaft. Its upper end, or head, articulates in the glenoid cavity of the scapula; below, its lower end is wonderfully moulded to form a hinge joint with the radius and ulna. First of all the prominent head must be studied; it is almost a true hemisphere and very smooth, fitting as it does into the glenoid cavity of the scapula. Below the head there runs a circular groove as if the bone were constricted; this is called the anatomical neck. Below the latter are two tuberosities which flank a groove for the tendon of the biceps muscle. One is called the greater tubercle and is on the lateral side of the bone, while the other is on the front of the bone and is known as the lesser tubercle. Both these eminences give origin to muscles, which are dealt with later. This area is connected with numerous muscles which are involved in the movement of the shoulder joint. Below the area of the tuberosities the bone appears to narrow slightly, the constriction being called the surgical neck. The shaft of the bone is smooth and slightly bent but its thickness is fairly consistent. Starting as a cylinder, it gradually becomes prismoidal and eventually terminates in a fan-shaped flattened portion at the elbow. There is a rough area about the middle of the outside of the shaft called the deltoid tubercle; to this are fixed the terminal fibres of the deltoid muscle after it completes the rounded fleshy prominence of the shoulder. The posterior surface of the bone is

almost entirely occupied by the heads of the triceps muscle, the heads being divided by the radial groove which winds round the shaft, downwards and laterally, containing the radial nerve. The

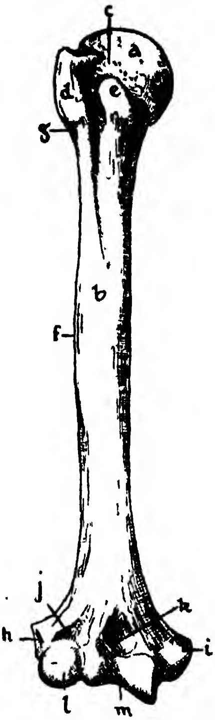


Fig. 56.—The Right Humerus. Anterior Aspect.

a, Head. *b*, Shaft. *c*, Anatomical neck. *d*, Greater tubercle. *e*, Lesser tubercle. *f*, Deltoid tubercle. *g*, Surgical neck. *h*, Lateral epicondyle. *i*, Medial epicondyle. *j*, Radial fossa. *k*, Coronoid fossa. *l*, Capitulum. *m*, Trochlea.

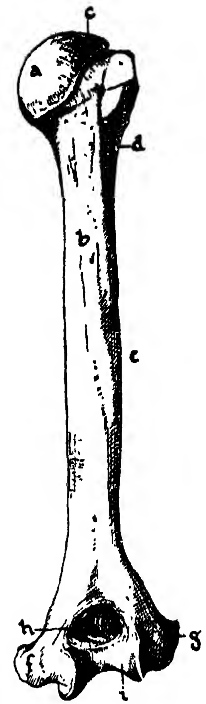


Fig. 57.—The Right Humerus. Posterior Aspect.

a, Head. *b*, Shaft. *c*, Anatomical neck. *d*, Surgical neck. *e*, Radial groove. *f*, Medial epicondyle. *g*, Lateral epicondyle. *h*, Olecranon fossa. *i*, Trochlea.

lower end of the humerus is irregular and distinctive; the bone spreads out to form two lateral knobs of bone which we can easily feel on our own arms, the medial and lateral epicondyles; these points give origin to groups of muscles which turn the forearm. The ulnar nerve passes over a shallow groove on the medial

epicondyle; very often this point is called the "funny bone" because in injuries the nerve is bruised and causes a tingling sensation, felt all down the forearm. The articular surfaces participate in the formation of a hinge joint and show a rounded smooth capitulum laterally and a saddle-like trochlea on the medial aspect. The former acts with the radius bone, the latter with the ulna. Three fossa are found at the lower part of the humerus, 2 in front and 1 behind. A small one is situated just above the capitulum, the radial fossa, so-called because when the forearm is fully bent on the upper arm the head of the radius bone fits into it. A larger fossa, called the coronoid fossa, is found just above the trochlea; this also receives a part of a bone—the coronoid process of the ulna when the forearm is fully bent. The greatest cavity of the 3 is situated on the posterior surface of the bone just above the trochlear margin. This is the olecranon fossa; when the forearm is straight, the head of the ulna (elbow bone), which is the point we can easily feel when the arm is bent, fits into it and for all practical purposes locks the joint (Figs. 56 and 57).

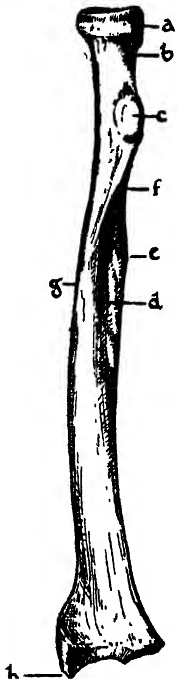


Fig. 58.—The Right Radius. Anterior Aspect.

a, Head. *b*, Neck. *c*, Radial tubercle. *d*, Shaft. *e*, Medial border. *f*, Oblique line. *g*, Lateral border. *h*, Styloid process.

The Radius

With the forearm in the position of full supination, the radius lies to the outside of its neighbour the ulna. In cross-section, the radius is triangular from the base for three-quarters of its length upwards then it tends to become circular. It has a head and a flattened distal end like the humerus, but the features are not so distinctive. It should be noted that although the radius and ulna are closely associated in the forearm they touch only at two points viz. the extreme ends of the radius. The radius is easily recognized by its characteristic "drumstick" head, which is cupped and smooth on its upper surface to articulate with the capitulum of the humerus and has a disc-like margin to which is fitted, like a leather belt on a wheel, the annular ligament, a tie between the ulna and radius. The inner part of the head of the radius works on the smooth radial notch of the ulna. Below the head the bone becomes constricted

into a neck; a little lower down on the internal surface is the radial tubercle which is roughened at the area into which the fibres of the biceps muscle are inserted. The shaft is slightly curved laterally, and shows a sharp medial border for the attachment of the interosseous membrane. Eight muscles are attached to its surface. The upper portion is marked by an oblique line which gives origin to the flexor muscles of the hand. The lower end shows a small indentation where the radius is in touch with the ulna, this is known as the ulnar notch or sigmoid cavity. The lateral aspect of the bone is prominent, curving down to a pyramidal peak, well known as the styloid process of the radius; it is often the site of fracture and is important since one of the main ligaments binding the wrist springs from it. The reverse side of the lower end of the radius is marked by a series of parallel furrows which are bony grooves for tendons of the extensor muscles of the hand. There is a small tubercle of bone here called the dorsal tubercle, which is flanked by the grooves mentioned above. Looking at the articular surface of the radius, we see that it is divided by a slight ridge into two smooth areas which are normally in contact with the semilunar (or lunate) bone, and the navicular (or scaphoid) bone of the carpus (Figs. 58 and 59).

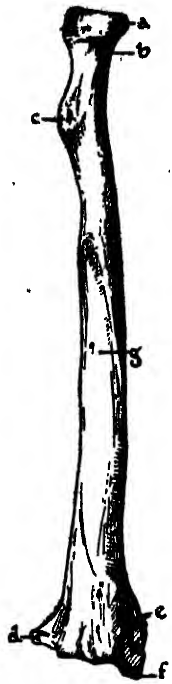


FIG. 59.—THE RIGHT RADIUS. POSTERIOR ASPECT.

a, Head. *b*, Neck. *c*, Radial tubercle. *d*, Sigmoid cavity. *e*, Grooves for tendons. *f*, Styloid process. *g*, Shaft.

The Ulna

The ulna is longer than the radius and its upper end forms the main part of the elbow joint whereas its lower end takes little part in the wrist joint as compared with the radius. The ulna is therefore a spike-like bone, gradually tapering to a point from above downwards. The most prominent portion of the bone is the olecranon process which forms the upper end of the bone and is scooped out anteriorly to articulate with the trochlea of the humerus. The sharp "beaked" process fits into the olecranon fossa on the back of the humerus and its posterior point can be recognized, when

the forearm is bent, as the point of the elbow, which is roughened for the insertion of the triceps muscle. A tuberosity of bone also projects forwards, completing the semilunar notch, which is the

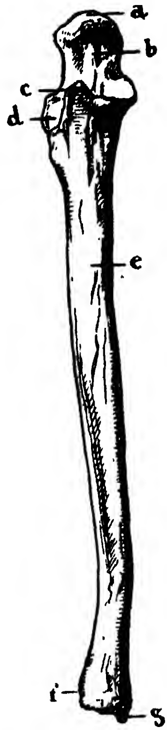


FIG. 60.—THE RIGHT ULNA. ANTERIOR ASPECT.

a Olecranon process. *b*, Semilunar notch. *c*, Coronoid process. *d*, Radial notch. *e*, Shaft. *f*, Head. *g*, Styloid process.

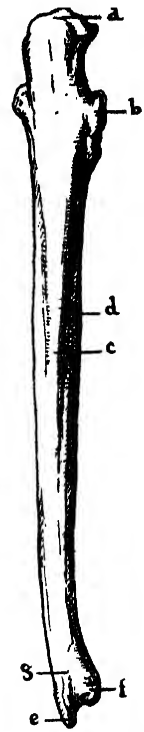


FIG. 61.—THE RIGHT ULNA. POSTERIOR ASPECT.

a, Olecranon process. *b*, Radial notch. *c*, Shaft. *d*, Lateral border. *e*, Styloid process. *f*, Head. *g*, Groove for extensor tendon.

whole articular area of the ulna with the humerus. This projection is called the coronoid process, and its point fits into the coronoid fossa of the humerus when the forearm is fully bent. On its lower surface the brachialis anticus muscle is inserted. On its medial aspect there are roughened eminences for ligaments and muscles. On the lateral aspect is the radial notch, which receives the head of the radius and allows the disc-like edge to revolve in it. The shaft gives attachment to 9 muscles; the lateral margin is rather sharp and forms a line from which the

interosseous membrane springs. The head of the ulna is at the lower end. A small articular area, in touch with the ulnar notch of the radius, forms part of the inferior radio-ulnar joint; another

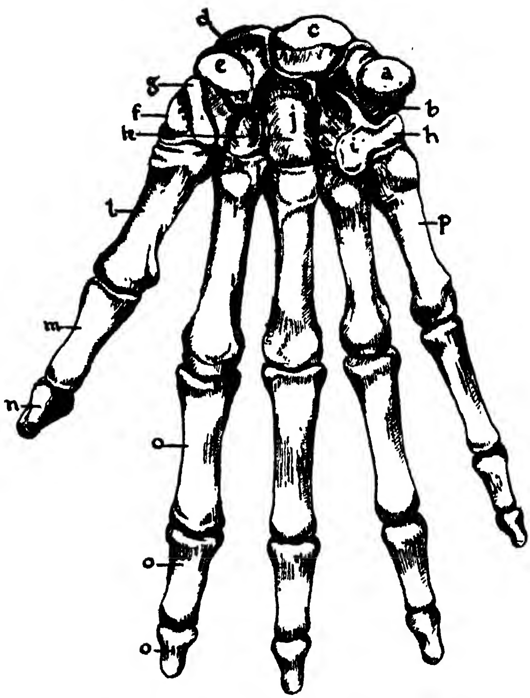


FIG. 62.—THE RIGHT HAND. VOLAR ASPECT.

a, Pisiform. *b*, Triquetral. *c*, Lunate. *d*, Navicular. *e*, Tubercle of navicular. *f*, Greater multiangular. *g*, Ridge of greater multiangular. *h*, Hamate. *i*, Hook of hamate. *j*, Capitate. *k*, Lesser multiangular. *l*, 1st metacarpal. *m*, 1st phalanx of thumb. *n*, 2nd phalanx of thumb. *o*, Phalanges of first finger. *p*, 5th metacarpal.

meets the disc of cartilage separating the ulna from the wrist. A smaller but more prominent process of bone projects downwards on the medial aspect of the lower end of the bone, forming the styloid process, a point of attachment for the medial ligament. At its base is a well marked groove for the tendon of a muscle, the extensor of the wrist (Figs. 60 and 61).

The Carpus

The carpus is made up of 2 rows of 4 bones each, compactly arranged to fit together in very close fashion; it is the basis of the

hand and is a sort of buffer between the bones of the forearm and the bones of the fingers. All are short bones, with convex or concave smooth areas at their points of contact with other bones. In the 1st row, beginning mesially, we have the pisiform, the cuneiform or triquetral, the semilunar or lunate and the scaphoid or

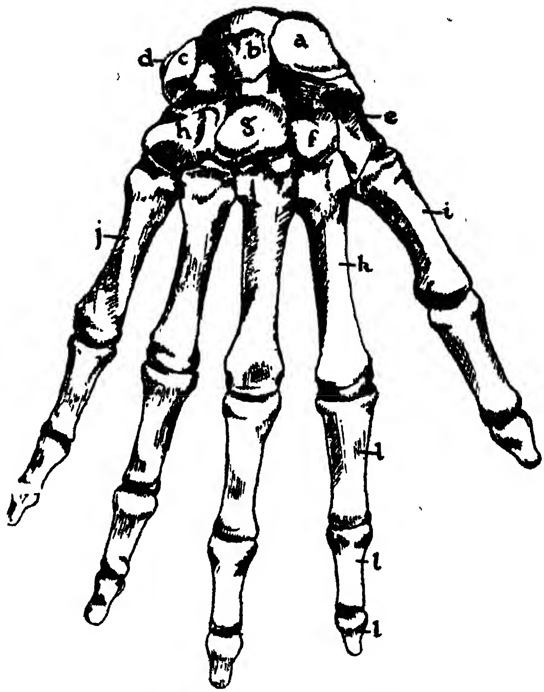


FIG. 63.—THE RIGHT HAND. DORSAL ASPECT.

a, Navicular. *b*, Lunate. *c*, Triquetral. *d*, Pisiform. *e*, Greater multiangular. *f*, Lesser multiangular. *g*, Capitate. *h*, Hamate. *i*, 1st metacarpal. *j*, 5th metacarpal. *k*, 2nd metacarpal. *l*, Phalanges.

navicular bones. In the 2nd row there are the unciform or hamate, the os magnum or capitate, the trapezoid or lesser multiangular and the trapezium or greater multiangular bones. We need not enter into a long description here of the various articulations of each of these bones but a few important points merit a word or two. First of all, only 3 bones of the 1st row take part in the wrist joint; the pisiform is set on the triquetral bone alone. On the palmar aspect of the carpus the hook of the

hamate, known also as the unciform process, is easily recognized; at the base of the thumb bone the greater multiangular bone is ridged for the attachment of a ligament and a muscle, the groove at the foot of the ridge transmitting the tendon of the flexor carpi radialis muscle. The back of the carpus is somewhat rounded and the individual bones are roughened. The lunate and navicular bones articulate with the radius. The relative positions of these bones may be studied by reference to Figs. 62 and 63.

The Metacarpus

There are 5 metacarpal bones, one corresponding to each finger. Each bone is a long bone in miniature, with a rounded head articulating with a phalanx and a base which is in association with one or more carpal bones. These bones are broader behind than in front and they are slightly concave on the palmar aspect. The 1st metacarpal bone is shorter than the others and is associated with the thumb; the 2nd at its base is in touch with the greater multiangular, lesser multiangular and capitate, also the third metacarpal bone; the 3rd metacarpal bone articulates with the capitate; the 4th has a small base and articulates with the hamae bone; the 5th is also in touch with the hamate bone (see Figs. 62 and 63).

The Phalanges

With the exception of the thumb, which has 2 phalanges, each finger has 3 of these small bones, which, as the illustrations show, are miniature long bones forming the basic foundation of the fingers. The last row differs from the others in having the tips roughened for the pulpy flesh of the fingers (see Figs. 62 and 63).

CHAPTER 6

THE SKELETON—PELVIC GIRDLE AND LOWER EXTREMITY

OS INNOMINATUM. THE ILIUM. THE ISCHIUM. THE OS PUBIS. THE ACETABULUM. THE OBTURATOR FORAMEN. THE FEMUR. THE TIBIA. THE FIBULA. THE PATELLA. THE TARSUS. THE TALUS. THE CALCANEUM. THE NAVICULAR BONE. THE CUBOID BONE. THE CUNEIFORM BONES. THE METATARSUS. THE PHALANGES.

The lower extremity is very much the same in composition as the upper. It is true there is only one bone, the os innominatum, forming the pelvic girdle and representing the clavicle and scapula of the upper extremity, but the os innominatum is really the result of a fusion of bones and its anterior portion can easily be recognized as the homologue of the clavicle, while its broad iliac plate with the acetabulum is the representative of the scapula. The thigh bone, or femur, is a single bone like the humerus; the tibia and fibula of the leg are much the same as the radius and ulna; while the kneecap may be imagined as something akin to an olecranon process which has become detached. The bones of the foot resemble in most aspects the bones of the hand.

Os Innominatum

No doubt the old anatomists, after much head-scratching, came to the conclusion that this bone could not be likened to any of the things around them and so they decided to call it the "unnamed bone." It will be understood that it is difficult to describe. It is a large, flat plate-like bone, twisted about its middle to form two planes almost at right angles to one another. The two innominate bones together make up most of the walls of the pelvis on each side. The innominate bone unites with the sacrum behind, but in front its anterior portions are tightly wedged together to form the symphysis pubis. The bone is not complete until puberty; up to this time there are 3 distinct bones, the ilium, the ischium and the os pubis; these then unite at a large cup-shaped depression on the lateral surface of the bone which, as the acetabulum, is the socket for the head of the femur (Figs. 65 and 66).

The Ilium.—This is the plate above the acetabulum, forming the upper bony shell of the pelvis. On its external aspect it presents a thick crest, rough at its margins for the attachments of several abdominal muscles and rising to a blunt peak at its middle. This crest ends in two spines, one in front and one behind. The anterior superior spine is one of the main landmarks of the lower abdomen, since its tip can be felt and often seen on either

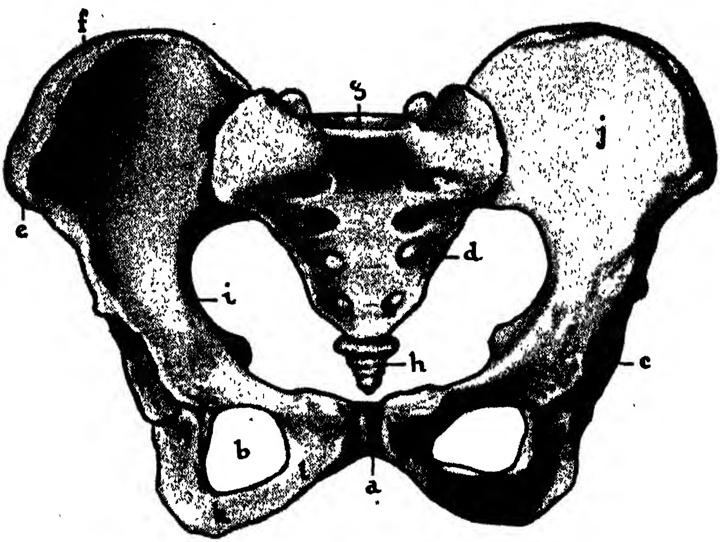


Fig. 64.—The Pelvis. Anterior Aspect.

a, Symphysis pubis. *b*, Obturator foramen. *c*, Acetabulum. *d*, Sacrum. *e*, Anterior superior spine. *f*, Crest. *g*, Articulates with 5th lumbar vertebra. *h*, Coccyx. *i*, Iliopectineal line. *j*, Ilium. *k*, Ischium. *l*, Os pubis.

side above the groin. Certain important muscles are attached to it as well as the inguinal (formerly Poupart's) ligament which stretches across to the pubic part of the bone. Just below the anterior superior spine is the anterior inferior spine, which gives origin to a tendon of the large muscle in front of the thigh, the rectus femoris. The notch between these eminences is occupied by the lateral femoral cutaneous nerve. The posterior superior spine and the posterior inferior spine also give rise to important ligaments and muscles. Below the posterior inferior spine is a large indentation called the greater sciatic notch, through which pass many nerves and blood vessels, the chief being the sciatic nerve. Three curved ridges are distinct on the outer surface of the ilium; they are known as the gluteal ridges, since the massive

muscles of the hip, the gluteus minimus, the gluteus medius and the gluteus maximus, spring from the areas enclosed by them.

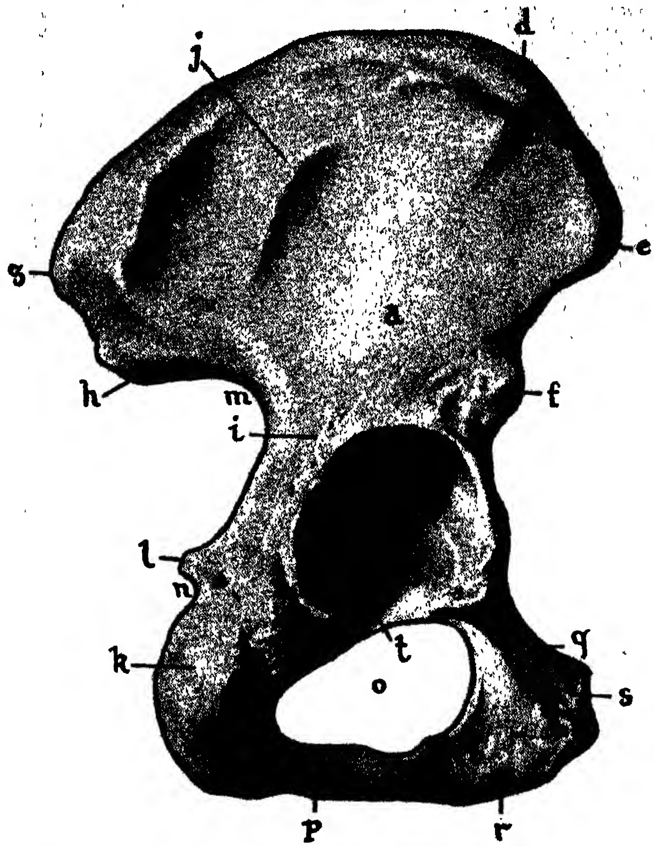


FIG. 65.—THE RIGHT OS INNOMINATUM. EXTERNAL ASPECT.

a, Ilium. *b*, Os pubis. *c*, Ischium. *d*, Crest of ilium. *e*, Anterior superior spine. *f*, Anterior inferior spine. *g*, Posterior superior spine. *h*, Posterior inferior spine. *i*, Groove for tendon. *j*, Ridge. *k*, Tuberosity of ischium. *l*, Spine. *m*, Greater sciatic notch. *n*, Lesser sciatic notch. *o*, Obturator foramen. *p*, Inferior ramus of ischium. *q*, Superior ramus of pubis. *r*, Inferior ramus of pubis. *s*, Forms the symphysis pubis. *t*, Acetabular notch.

Just above the acetabulum is a groove for the reflected tendon of the rectus femoris muscle.

The inner surface of the bone is for the most part smoother, forming a concave surface known as the iliac fossa. From this

area springs the iliacus muscle, its lower boundary being formed by a prominent ridge, the arcuate line. The latter marks the

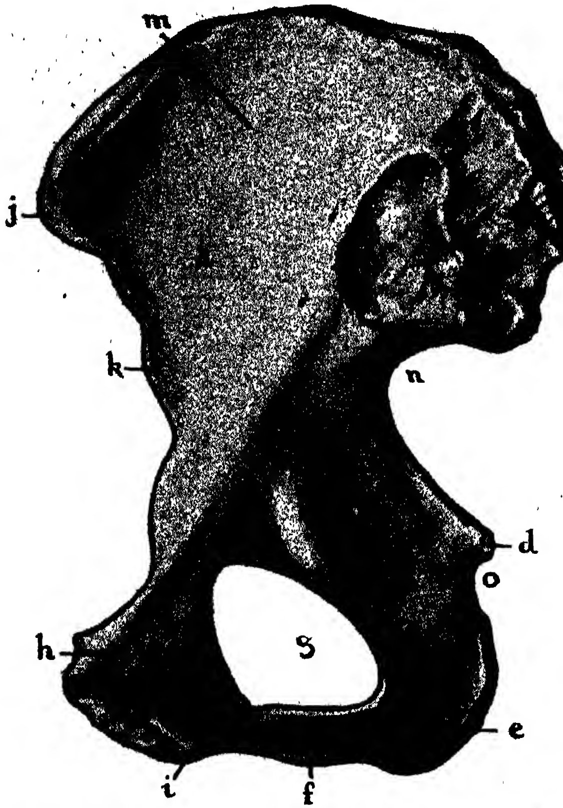


FIG. 66.—THE RIGHT OS INNOMINATUM. INTERNAL ASPECT.

a, Ilium. *b*, Pubis. *c*, Ischium. *d*, Ischial spine. *e*, Tuberosity of ischium. *f*, Inferior ramus. *g*, Obturator foramen. *h*, Superior ramus of pubis. *i*, Inferior ramus of pubis. *j*, Anterior superior spine. *k*, Anterior inferior spine. *l*, Auricular area. *m*, Iliac fossa. *n*, Greater sciatic notch. *o*, Lesser sciatic notch.

upper limit of the true pelvis. Just behind the iliac fossa is a rough L-shaped area, said to have the outline of a human ear and therefore called the auricular area. This is the surface of articulation with the sacrum (Figs. 65 and 66).

The Ischium.—The ischium is the lowest part of the bone and forms a strong rounded point on which the trunk rests when the sitting posture is assumed. This firm mass of bone is known as the tuberosity of the ischium. Several muscles and ligaments are attached to it. The body of the ischium forms about two-fifths of the acetabulum, and the ramus superior and ramus inferior complete the angle of the bony wall which encloses the obturator foramen. The posterior portion of the body is a part of the greater sciatic notch. The spine of the ischium is a peak of bone which is the lower limit of the notch; it gives rise to several muscles and ligaments. Between this spine and the tuberosity is the lesser sciatic notch, through which passes the tendon of the obturator internus muscle, the obturator nerve and the pudendal nerve and blood vessels. The inferior ramus forms the lower border of the obturator foramen and runs forwards to join the inferior ramus of the os pubis (Figs. 65 and 66).

The Os Pubis.—This is the front bony pillar of the innominate bone, somewhat similar in construction to the ischium in that it has a body and superior and inferior rami. The thickest part of the body is rough at the area which is in close contact with its neighbour; the two form the symphysis pubis. Its upper part is called the crest, a bony eminence crowned by a tubercle which gives attachment to the inguinal ligament. The superior ramus runs upwards to form part of the acetabulum and its posterior border forms a part of the rim of the obturator foramen. The inferior ramus runs downwards to join the inferior ramus of the ischium. Many muscles of the thigh originate from the pubic bone; these may be studied in detail later on (Figs. 65 and 66).

The Acetabulum.—Frequent reference has been made above to the bones forming the acetabulum, which may be likened to a central circus in the middle of the 3 bony planes. The head of the femur works in this cavity, very much in the same way as the head of the humerus works in the glenoid cavity. $\frac{1}{5}$ is formed by the pubic bone, $\frac{2}{5}$ by the ilium, and $\frac{2}{5}$ by the ischium There is a wide shelf of bone forming a sort of ledge over a slightly deeper part of the cavity, which contains fat and vessels in the living subject. The shelf is deficient at its lower part, forming a gap which allows the passage of important vessels and nerves. This gap is called the acetabular notch and to its margins is attached the ligamentum teres, which moors the head of the femur to the cavity. The notch is closed by the transverse ligament. Immediately below the acetabulum is a groove for the tendon of the obturator externus muscle (Fig. 65).

The Obturator Foramen.—The last area to be considered is one which has already been mentioned in the description of the other parts of the innominate bone, since it is a space enclosed by

the borders of the ilium, the ischium and the pubes. This great ovoid canal is partly closed by a membrane called the obturator membrane, which leaves a groove above through which the obturator nerve and vessels pass from the pelvis into the thigh (Fig. 66).

The Femur

Of all the bones in the body the femur, or thigh bone, is outstanding by reason of its size, its strength and its length. It roughly consists of a cylindrical shaft with two extremities, the upper forming part of the hip joint and the lower part of the knee joint. The nurse should form a clear idea about the attitude of this bone; it lies obliquely in the thigh, its axis inclining towards the middle line as it extends from the acetabulum to the knee. The two thigh bones can be made to touch at the knees; thus a triangle is formed by the mass of the pelvis as base and the right and left femur as the sides of the triangle. In the female the base of this triangle is always comparatively longer than that of the male skeleton, therefore most women have a tendency to knock-knee.

Taking the various features of the bone from above downwards, we have first a rounded head, which fits into the cup of the acetabulum, forming a very good ball-and-socket joint. At a certain point just below the middle of the rounded surface (which is about $\frac{3}{5}$ of a sphere in all) is a small roughened area, the fovea capitis femoris, which is the point at which the round ligament (ligamentum teres) is attached. Below the head, the bone narrows into a neck of considerable importance, since it sustains much weight and strain of the body. This is provided for by a hardening of the cancellous bone into a core which is called the calcar femorale. The neck of the femur forms an angle with the shaft which averages 122° in the adult, but which tends to lessen in old age. The neck broadens out into two well defined "shoulders," the greater and the lesser trochanters. The greater trochanter forms a prominent quadrilateral mass on the lateral aspect of the shaft and the lesser trochanter a conical elevation on the medial side posteriorly. We get the impression that the neck has been pressed hard into a bulbous end of the shaft, causing the two processes to bulge out. The greater trochanter rises up into a ridge the summit of which is almost on a level with the head of the bone. The rough surface externally is the area of insertion of the gluteal muscles, the obturator internus muscle, the gemelli and the piriformis, while the tendon of the gluteus maximus plays over a smooth surface of the bone. In the groove formed by the junction of the neck and great trochanter there is inserted the obturator externus muscle; the groove is called the digital or trochanteric fossa. The lesser trochanter has a small muscle area for the psoas major. Between these prominences are

distinct lines, anteriorly and posteriorly. The anterior line is known as the intertrochanteric line and marks the attachment of the capsule of the hip; the posterior is called the intertrochanteric

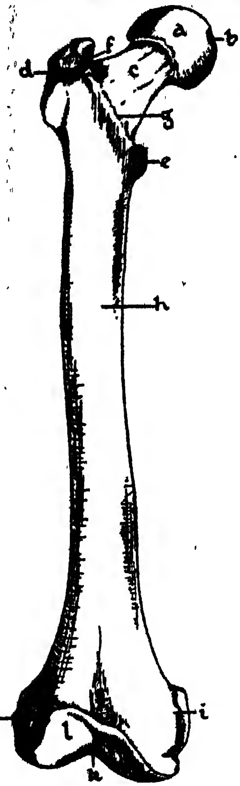


FIG. 67.—THE RIGHT FEMUR. ANTERIOR ASPECT.

a, Head. *b*, Fovea capitis femoris. *c*, Neck. *d*, Greater trochanter. *e*, Lesser trochanter. *f*, Digital fossa. *g*, Intertrochanteric line. *h*, Shaft. *i*, Medial epicondyle. *j*, Lateral epicondyle. *k*, Intercondyloid fossa. *l*, Articulates with the patella.

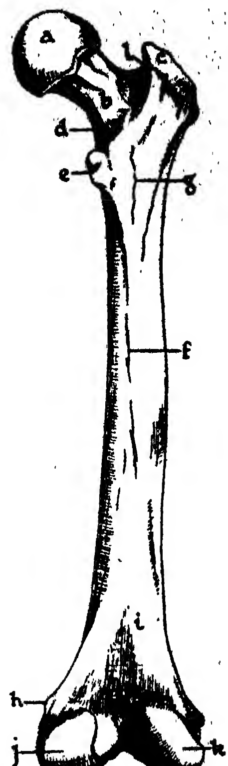


FIG. 68.—THE RIGHT FEMUR. POSTERIOR ASPECT.

a, Head. *b*, Neck. *c*, Greater trochanter. *d*, Intertrochanteric crest. *e*, Lesser trochanter. *f*, Linea aspera. *g*, Spiral line. *h*, Adductor tubercle. *i*, Popliteal surface. *j*, Medial condyle. *k*, Lateral condyle.

crest, which is broken by the quadrate tubercle for the quadratus femoris muscle. Just above this crest is the line of attachment of the articular capsule. The shaft of the femur is long, widening

out at both ends, especially at the lower extremity. There is a slight forward bending of the axis and the bone is somewhat flattened posteriorly. The transverse section of the shaft may be said to be circular, although at the centre, where the bone becomes narrower, the outline approaches a triangular shape. There are several important landmarks on the front, back and sides of the shaft. Taking the posterior surface first, we find that the middle third of the bone is marked by a prominent ridge in the middle of the long axis of the femur; this is called the linea aspera. Various muscles are attached to the sides of this groove, which sends out 3 bony ridges above and 2 below. Of the 3 above, one goes towards the greater trochanter and as it gives insertion to the gluteus maximus muscle it is called the gluteal tuberosity; another goes to the base of the lesser trochanter and is known as the pectineal line; the third is known as the spiral line and joins the intertrochanteric line. Upon this bony ridge are fixed several muscles including the vastus medialis, vastus lateralis, the pectineus and the adductor muscles of the thigh. The two inferior ridges sweep out towards the epicondyles, the medial one showing a small groove about its middle for the femoral vessels and terminating in a prominence above the medial condyle called the adductor tubercle. These two ridges enclose a smooth triangular space known as the popliteal surface. It is the bed of the popliteal artery.

The lower end of the femur forms one of the landmarks of the body, constituting the upper half of the knee. The bone becomes widened out into a club-like termination split by the intercondyloid fossa or notch to form 2 condyles, a lateral and a medial. The lateral condyle is slightly higher up than the medial and is shorter and broader, its inferior surface being smooth and horizontal for articulation with the tibia, while in front the articular surface extends up the bone and is in touch with the patella. Various ligaments and muscles are attached to its rough lateral surface, chief of which is the lateral head of the gastrocnemius muscle—the muscle which constitutes the fleshy mass of the calf. The medial condyle is longer than the lateral and articulates with parts of the tibia and patella also. The medial head of the gastrocnemius muscle arises from its medial border. Looked at from the front, therefore, the bone shows a flap of smooth articular surface, somewhat saddle-shaped and forming a veneer over the central portions of the condyles. This area is in close contact with the patella. Behind, the 2 condyles are split into 2 almost equal kidney-shaped articular areas, both of which act in conjunction with the tibia below. The deep groove between, the intercondyloid fossa, gives attachment to the crucial ligaments of the knee joint. A bony tubercle, corresponding to the adductor tubercle but on the lateral aspect of the

bone is known as the lateral epicondyle and to it is attached the fibular collateral ligament (Figs. 67 and 68).

The Tibia

Commonly called the shin bone, this bone is the mainstay of the leg below the knee; like the ulna, it is broader above than below and consists of a prismoidal shaft with two extremities which are considerably wider. The tibia lies mesially to the fibula; these two bones together form the framework of the leg just as the radius and ulna form the framework of the forearm. The tibia is the second longest bone of the body.

The head of the bone is the most expanded portion. It can be divided roughly into 2 tuberosities or condyles the upper surfaces of which articulate with the femur and are concave and smooth. Between them a prominent intercondyloid eminence, called the spine, makes the division clear. This bony tubercle is bifid, giving attachment both to the crucial ligaments of the knee joint and to the semilunar cartilages, which not only deepen the articular area but also form important shock-absorbing pads for the knee joint. At the mid-point of the lower aspect of the front of the tibial head is a well known point to which the ligament of the kneecap is attached. It is called the tubercle of the tibia and is quite easily felt in the living subject. Immediately behind the spine and forming a depression between the condyles is an area known as the posterior intercondyloid fossa, or popliteal notch; this gives attachment to the posterior crucial ligament. On the back of the medial condyle is a small horizontal groove for the semimembranosus muscle, while on the same level at the lateral aspect is a facet on which the head of the fibula works. One other feature should be noted: an oblique low ridge runs medially and downwards, and gives attachment to the soleus muscle—the soleal line; above it is a large area for the popliteus muscle continuous with popliteal space of the femur.

The shaft of the tibia is characterized by 3 very sharp ridges. The anterior crest is known to the layman as the shin and is the site of many painful indentations during a lifetime, as we all know to our cost. The other two ridges form respectively the medial and lateral edges of the bone. The cross-section of the tibia is therefore triangular in outline and of the 3 surfaces the medial is covered by skin alone (this we can prove for ourselves), the lateral is covered by a muscle known as the tibialis anterior, while the posterior lies deeply, giving origin to the fibres of the flexor longus digitorum muscle. Between the tibia and fibula there stretches a fine membrane, the interosseous membrane. A nutrient foramen, believed to be the largest in the body, is prominent posteriorly below the popliteal ridge.

The lower extremity of the tibia is expanded like the upper, but with lesser range. It forms part of the ankle joint and is often the site of fracture. The bone forms a pointed nodule on its medial side, the medial malleolus, which can also be easily made

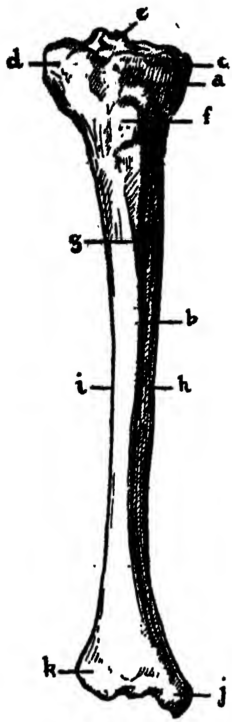


FIG. 69. — RIGHT TIBIA. ANTERIOR ASPECT.

a, Head. *b*, Shaft. *c*, Medial condyle. *d*, Lateral condyle. *e*, Spine. *f*, Tubercle. *g*, Anterior crest. *h*, Medial border. *i*, Lateral border. *j*, Medial malleolus. *k*, Articulation with fibula.

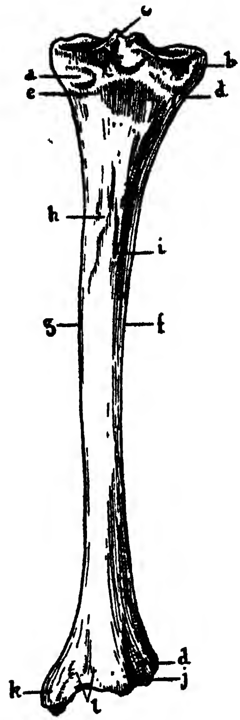


FIG. 70. — RIGHT TIBIA. POSTERIOR ASPECT.

a, Medial condyle. *b*, Lateral condyle. *c*, Spine. *d*, Facets for articulation with the fibula. *e*, Groove for semimembranosus. *f*, Lateral border. *g*, Medial border. *h*, Soleal ridge. *i*, Foramen. *j*, Flexor groove. *k*, Medial malleolus. *l*, Grooves for tendons.

out as the bony prominence on the medial side of the ankle. To it is attached the deltoid ligament, while on its outer aspect, which is smooth, is the area of articulation with the talus bone of the foot. Behind there is a prominent groove in which lie the tendons of the tibialis posterior muscle and the flexor longus

rounded lower point a strong ligamentum patellae passes to be inserted into the tubercle of the tibia. Behind, the bone shows almost entirely a smooth articular surface divided by a vertical ridge into 2 areas, one of which is in contact with the lateral condyle of the femur and another with the medial condyle of the femur. The patella can be moved about freely when the joint is partially relaxed. A fairly thick border exists especially at the upper region. The patella is a very important factor in the stability of the erect posture and when fractured brings about a situation in which the outlook for the future is very uncertain (Figs. 73 and 74).

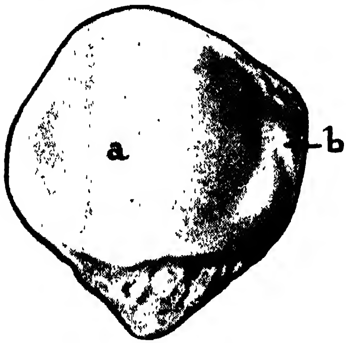


FIG. 74.—LEFT PATELLA. POSTERIOR ASPECT.

a, Surface for articulation with the lateral condyle of femur. *b*, Surface for articulation with the medial condyle of femur.

The Tarsus

This is analogous to the carpus in the hand, forming as it does a basis of the foot and taking part in the arch. Seven bones constitute the tarsus; these are arranged into 2 rows, medial and lateral. The lateral row contains the calcaneum and the cuboid bone. The medial row, from behind forwards, consists of the astragalus or talus, the scaphoid or navicular and 3 cuneiform bones which form the terminal transverse group. All these bones are typical short bones, their compact tissue enclosing cancellous matter which is especially strong in order to support the whole weight of the body when a person is standing. Together with the metatarsal bones the carpal bones make up 4 arches, a medial longitudinal arch and a lateral longitudinal arch (both of which are completed by the heads of the metatarsal bones) and 2 transverse arches, one through the tarsus proper and one farther forward, formed by the heads of the metatarsal bones. In flatfoot (a common trouble in teachers, policemen and shopkeepers, all of whom have long hours of standing), one or more of these arches loses its stability and the result is a varying degree of lowering of the bones, with consequent pain and discomfort (Figs. 75, 76, 77 and 78).

The Talus.—Very little of this bone is seen on the plantar surface of the foot but it is prominent on the dorsum, where it supports the tibia. It has a head, neck, body and trochlea. On either side it articulates with a malleolus while below it is in

contact with the calcaneum. The bone is easily recognized, its trochlear element forming the summit of the tarsus. The head

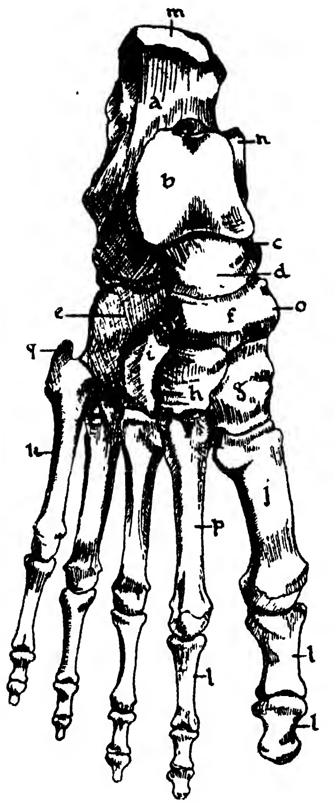


FIG. 75.—RIGHT FOOT. DORSAL ASPECT.

a, Calcaneum. *b*, Trochlear surface of talus. *c*, Neck of talus. *d*, Head of talus. *e*, Cuboid. *f*, Navicular. *g*, 1st cuneiform. *h*, 2nd cuneiform. *i*, 3rd cuneiform. *j*, 1st metatarsal. *k*, 5th metatarsal. *l*, Phalanges. *m*, Area for attachment of tendo calcaneus. *n*, Sustentaculum tali. *o*, Tubercle. *p*, 2nd metatarsal. *q*, Tubercle of 5th metatarsal.

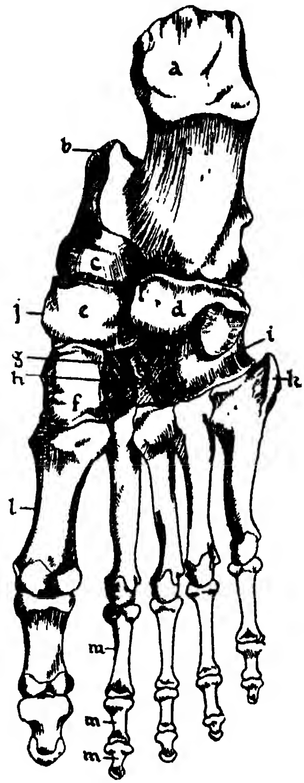


FIG. 76.—RIGHT FOOT. PLANTAR ASPECT.

a, Calcaneum. *b*, Sustentaculum tali. *c*, Talus. *d*, Cuboid. *e*, Navicular. *f*, 1st cuneiform. *g*, 2nd cuneiform. *h*, 3rd cuneiform. *i*, Groove for tendon. *j*, Tubercle. *k*, Tubercle of 5th metatarsal. *l*, 1st metatarsal. *m*, Phalanges.

is rounded and articulates with the navicular bone. This narrows into a neck which again becomes wider to form the body.

On the under surface of the bone are 3 smooth facets which mark the areas of articulation with the calcaneum, upon which the astragalus rides. A well defined groove, the sulcus tali, lies in front of the posterior calcaneal articular surface.

The Calcaneum.—The heel bone is the largest of the tarsal group. It is situated at the lowest and most posterior part of the foot. It is important in giving attachment to the tendo calcaneus (Achilles tendon) and thus functioning as a lever for the muscles of the calf. It is easily recognizable as forming the prominence of the heel. We have seen how it articulates with the talus but it also articulates with the cuboid in front. A pro-

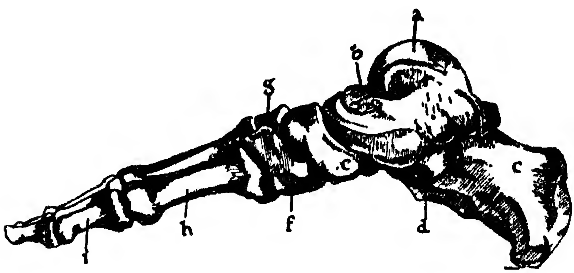


FIG. 77.—RIGHT FOOT. MEDIAL ASPECT.
a, Talus. *b*, Neck of talus. *c*, Calcaneum. *d*, Sustentaculum tali. *e*, Navicular. *f*, 1st cuneiform. *g*, 2nd cuneiform. *h*, 1st metatarsal. *i*, Phalanges.

minent flat process of bone projects from the medial aspect; this is known as the sustentaculum tali and contains facets for articulation with the talus; it is a useful landmark, enabling the student to say at once to which side the bone belongs. Below it there is a groove which lodges the flexor longus hallucis and certain vessels and nerves. Eight muscles are attached to this bone, also the strong fibrous plantar fascia which gives great strength to the foot (Figs. 75, 76, 77 and 78).

The Navicular Bone.—This is a simple bone, said to be boat-shaped and having 5 articular facets viz. 3 anteriorly for each of the cuneiform bones, 1 posteriorly for the talus and 1 on the lateral aspect for the cuboid. The one landmark of note is the tubercle of the navicular on the medial side, a prominence to which is attached the tendon of the tibialis posterior muscle (Figs. 75, 76, 77 and 78).

The Cuboid Bone.—Behind this bone is the calcaneum, in front the two lateral metatarsal bones. On its plantar surface is a deep groove for the tendon of the peroneus longus muscle. The

bone articulates with the 3rd cuneiform bone and occasionally with the talus (Figs. 75, 76, 77 and 78).

The Cuneiform Bones.—These 3 bones are all more or less alike and of wedge-shaped pattern, articulating with the scaphoid behind and with the 1st, 2nd and 3rd metatarsals in front. The first cuneiform bone has a tubercle on its plantar surface to which both the tibialis anterior and posterior are attached (Figs. 75, 76, 77 and 78).

The Metatarsus

The metatarsal bones are very similar to the metacarpal bones, having a shaft and 2 extremities. The tarsal extremity, or

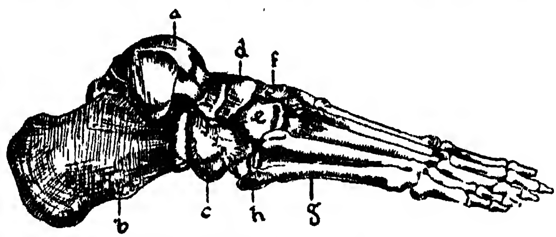


FIG. 78.—RIGHT FOOT. LATERAL ASPECT.
a, Talus. *b*, Calcaneum. *c*, Cuboid. *d*, Navicular. *e*, 3rd cuneiform. *f*, 2nd cuneiform. *g*, 5th metatarsal. *h*, Tuberosity of 5th metatarsal.

base, articulates with the tarsal bones while the head, or phalangeal extremity, articulates with the base of the phalanges. The metatarsals also articulate with each other at their bases, where they are firmly pressed together. The 1st metatarsal bone is in connection with the great toe, is much shorter, thicker and stronger than the others, and forms the medial border of the foot. As in the other bones, certain flexor and extensor tendons are fixed to the head, which on its plantar surface has 2 sesamoid bones. The 2nd metatarsal bone is longer than the rest, and is wedged between 3 cuneiform bones. The 5th metatarsal bone is distinguished by a lateral spur of bone which can be felt in the living subject; it is called the tuberosity (Figs. 75 and 76).

The Phalanges

Fourteen are present, as in the hand. Similarly too, as in the thumb, there are only 2 bones in the great toe, but they are much broader and thicker than the others. Every phalanx has a head, a base and a body, and is convex on the superior aspect. The bases articulate with the heads of their neighbours and with

the heads of the metatarsals. The heads of the terminal phalanges spread out in exactly the same way as those of the hand, to form a surface of fixation for the pulp of the toes and their respective nails.

CHAPTER 7

THE JOINTS

GENERAL FEATURES OF A JOINT. CLASSIFICATION OF JOINTS. MOVEMENTS OF JOINTS. ARTICULATIONS OF THE TRUNK. SPECIAL VERTEBRAL JOINTS. ARTICULATIONS OF THE UPPER EXTREMITY. THE SHOULDER JOINT. THE ELBOW JOINT. THE RADIO-ULNAR JOINTS. THE WRIST JOINT. THE CARPAL JOINTS. THE CARPOMETACARPAL JOINTS. THE JOINTS OF THE HAND AND FINGERS. THE ARTICULATIONS OF THE LOWER EXTREMITY. THE HIP JOINT. THE KNEE JOINT. THE TIBIOFIBULAR JOINTS. THE ANKLE JOINT. THE TARSAL JOINTS. OTHER JOINTS OF THE FOOT. THE ARCHES OF THE FOOT.

WE have learned that most of the bones act with other bones to allow movements and changes of position of the limbs and other parts of the body. While the main structure of a bone is for support and for stability it has also specialized areas, chiefly at the ends of the bones, for articulation with other bones. The part of the body which consists of 2 or more bones held together by various types of connective tissue and muscular tissue is called a joint. The science of the joints is arthrology.

General Features of a Joint

Constituents.—Generally speaking there are 5 chief elements in a joint, these being bone, hyaline cartilage, fibrocartilage, ligaments and synovial membrane.

Bone.—The ends of the long bones, the articular surfaces of irregular bones and other parts involved in joint structure are much harder than the normal compact bone, the articular lamellae being denser and smoother. Microscopical investigation shows that whereas the lacunae are larger, there are no Haversian canals and no canaliculi.

Hyaline Cartilage.—A thin layer of hyaline cartilage of varying depth covers the ends of bones; it is of the type described and illustrated on p. 13.

Fibrocartilage.—This variety is found in the pads between

bones, in the strong connections between bones, in the lining cartilages of cavities (e.g. the glenoid fossa of the scapula) and in the grooves.

Ligaments.—With 2 exceptions, the ligaments consist of white fibrous tissue. Their function is to bind bones together and to enclose joint spaces in which the highly sensitive articular surfaces are in operation. Ligaments thus form capsules for the joint. They are firm and strong, some being more elastic than others, depending upon the amount of mobility required at the particular joint.

Synovial Membranes.—A very delicate but very important film-like membrane spreads like a fine enamel over the structures inside the joint, excepting the hyaline cartilage. This has special cells, which manufacture and continually pour out a viscid fluid like very thin glue; this is the oil of the joint and it lubricates all the structures, the fluid being known as synovial fluid. Synovial membranes may also form small sacs; sometimes little closed bags are formed which when filled with fluid act as bursae, their function being to provide a cushion between bones or over bones which are pressed on from the outside. Tendons also have a covering of synovial membrane which gives their glistening surface free play when they are in action.

Classification of Joints

There are 3 chief classes of joints viz. fibrous joints (immovable); cartilaginous joints (slightly movable); synovial joints (joints which are freely mobile).

Fibrous Joint.—This is a fixed joint, no movement being allowed between the bones. Examples are the sutures of the skull and the teeth with their sockets, the latter representative of a gomphosis. There are many varieties of suture, depending upon the type of the articular processes (dentate, serrate, squamous and so on). Syndesmosis is another form of fibrous joint and is represented by the inferior tibiofibular joint, in which the ends of the bones are kept in apposition by an interosseous ligament.

Cartilaginous Joint.—In this type there is only slight movement, the articular surfaces of the bones being separated in most cases by the pads of cartilage. A symphysis is a joint in which there is no synovial membrane and the bones are joined together by fibrocartilage. Examples are the symphysis pubis and the intervertebral joints, in each of which pads of fibrocartilage are to be found.

Synovial Joint.—This class is a large one, and is subdivided according to the table given overleaf.

CLASSIFICATION OF SYNOVIAL JOINTS

Technical Name.	*Popular Name.*	*Description.*	*Examples.*
Ginglymus	Hinge joint	Acts in one plane, similar to a hinge; a rounded end moves in a deeply grooved end	The elbow joint
Trochoid	Pivot joint	Probably the most cleverly constructed joint, allowing rotation only	Joint between atlas and axis Superior radio-ulnar joint
Condyloid	Two-way joint	Allows movement in two planes; usually an ovoid head in an elliptoid cavity	The wrist joint
Saddle-articulation	Saddle joint	One convex surface receives a concave surface in two planes, permitting very wide movements	Carpometacarpal joint of the thumb
Articulatio cotylica	Ball-and-socket joint	The spherical head of a long bone fits into and moves within a cup-shaped cavity	The hip joint The shoulder
Plane joint	Gliding joint	Two flat surfaces gliding over each other with very limited movement	Carpal and tarsal joints

Movements of Joints

There are 4 chief movements described. Very often a joint is capable of several varieties of movement, which may be combined to execute difficult actions of the limbs and allow most intricate performances. The 4 movements are known as gliding movement, angular movement, rotation and circumduction.

Gliding Movement.—In regions such as the tarsus and carpus, many small articular facets are in close cooperation with similar surfaces on the neighbouring bones and at most the 2 flat surfaces move in a range which is very limited, usually amounting to a few millimetres.

Angular Movement.—The fundamental principle in this type of movement is movement of one arm of an angle (e.g. a finger, the lower limb, the forearm) through a certain number of degrees, the result being an increase or a diminution of the angle.

Flexion indicates a lessening of the angle and means a doubling up of the limb by the bending of one arm of the angle on the other. For example if we touch the shoulder with the tip of the fingers we are said to flex the elbow, the angle between the humerus and the radius and ulna being very acute. A similar action occurs when we bend the knee.

Extension is the opposite of flexion and usually means a straightening out of a limb. Taking the arm as our example again, in full extension the humerus, radius and ulna are for all practical purposes in one line, the angle between them being nearly 180°.

Abduction, as its name implies, is a carrying away of the part from the middle line. Thus if we stand in the anatomical position, with the arm fully extended downwards and the thumb towards the lateral aspect with the palm looking forwards, abduction of the right thumb would mean movement as far to the right as possible and abduction of the right arm would mean a carrying away of the right arm at the shoulder joint until the arm is horizontal.

Adduction is the reverse of abduction, meaning movement towards the middle line. If we stand with our heels together, our arms close by our sides and the thumbs touching the little fingers, we are in a position of adduction.

Rotation.—Strictly speaking this movement is confined to the rotation of the head of a bone in one plane, but it is rarely carried out without some circumduction, which is described below.

Circumduction —This indicates a double action e.g. flexion with rotation, abduction with rotation and so on. It comprises the movements at ball-and-socket joints and therefore is chiefly concerned with the hip and shoulder. The complicated accomplishments of these joints often involve all the angular movements plus rotation.

Articulations of the Trunk

The Temporomandibular Joint.—This is the articulation of the mandible with the temporal bone and therefore is concerned with shutting and opening the mouth. It has both gliding and hinge-like movements. Several ligaments bind the mandible to the skull, but sometimes the condyle slips out and causes an uncomfortable dislocation. The chief ligaments are one from the sphenoid (the sphenomandibular), one from the zygoma (the lateral), one from the styloid process ol the temporal bone to the ramus (the stylomandibular) and a capsular ligament which surrounds the neck of the condyle and the glenoid cavity of the temporal bone like a loosely fitting sleeve.

The Intervertebral Joints.—We already know that the vertebrae are in contact by means of their articular processes and also that one body rests on another, cushioned by a substantial disc of cartilage. The spine is very strong, flexible and rigid, therefore it is provided with several closely applied supporting bands of fibrous tissue.

The anterior longitudinal ligament runs down the whole length of the spine in front of the bodies.

The posterior longitudinal ligament binds together the segments at the back, passing from above downwards like an adhesive band.

The *ligamenta flava* consist of yellow elastic tissue and fix the laminae together.

The supraspinous and interspinous ligaments join up the spinous processes. In the region of the neck the ligament consists of yellow elastic tissue, and is called the *ligamentum nuchae.*

The intertransverse ligaments are the connections between the transverse processes.

In addition to the above ligaments the intervertebral discs are fibrocartilaginous pads between each vertebra, while the capsular ligaments are formed round the articular processes like small bags, each lined with a synovial membrane.

Special Vertebral Joints

1. *The Atlanto-axial Joint.*—The joint between the first two vertebrae is interesting and important, as it combines a gliding with a pivotal joint. The rotation of the head depends upon the fixation of the ligaments round the odontoid process of the axis, which together make a collar for the peg of bone and so keep it in place. In addition to the usual anterior and posterior ligaments and the capsular ligaments, there is a transverse ligament passing across the spinal foramen and lined by a synovial membrane acting as a restraining band behind the odontoid process. Small ligamentous processes pass upwards and downwards so that the name, cruciate, is often applied to this ligament.

2. *The Occipito-atlantal Joint.*—This is the method by which the skull is joined to the vertebral column. There are 6 ligaments, 2 springing from the front and back respectively of the foramen magnum, 2 lateral ligaments passing from the jugular processes of the occipital bone to the transverse processes of the atlas, and 2 capsular ligaments ensheathing the articular areas. This permits free nodding movements.

3. *The Occipito-axial Joint.*—Although the head does not articulate with the 2nd vertebra directly, it is closely tied to it, certain ligaments passing over the atlas and forming occipito-axial connections. The basi-occipital marks the termination of the posterior longitudinal spinal ligament, the portion between it and

the axis being called the *membrana tectoria.* Two strong fibrous bands pass from the odontoid process to the sides of the condyles of the occiput and are appropriately termed the check (or alar) ligaments. Finally, there is a " bearing rein " passing from the tip of the odontoid to the anterior rim of the foramen magnum and known as the suspensory or apical ligament.

The Ligaments of the Ribs.—The ribs are moored to the vertebrae by a series of costovertebral ligaments. Some of these join the head of the rib to the 2 associated vertebral bodies and the intervertebral disc; others are intra-articular in character, and fix the inside of the joint, running between the crest and the intervertebral disc. The tubercles of the ribs are connected with the transverse processes of the vertebrae by the costo-transverse articulations. At the sternal end the first rib is fixed; the other 6 form plane joints, each surrounded by anterior, posterior and capsular ligaments.

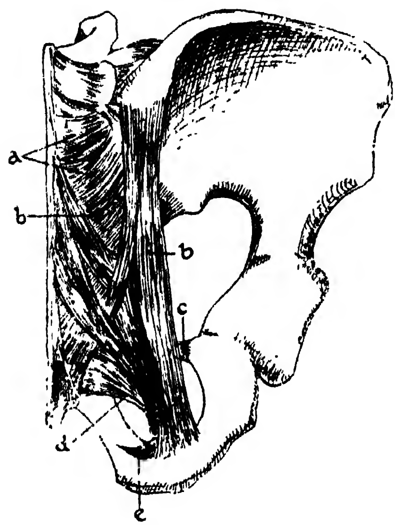


Fig. 79.—Posterior Aspect of the Sacro-iliac Joint and the Sacro-ischial Joint. Right Side.

a, Short posterior sacro-iliac ligament. *b*, Long ditto. *c*, Sacrospinous ligament. *d*, Sacrotuberous ligament. *e*, Falciform process.

The Sternum has an anterior and a posterior sternal ligament; a layer of fibrocartilage is inserted between the manubrium and the gladiolus.

The Sacrovertebral Ligaments.—In addition to the ligaments common to the rest of the spine, the sacrum has an iliolumbar ligament which runs from the 5th lumbar transverse process to the crest of the ilium. The sacrum and coccyx are bound together by anterior, posterior and lateral ligaments.

The Sacro-iliac Joint.—This is one of the most important of the cartilaginous joints especially in midwifery. It is often affected with rheumatism. The short, strong interosseous bands forming the interosseous ligaments are instrumental in keeping the sacrum wedged between the iliac bones. In front are the anterior sacro-iliac ligaments and behind the posterior sacro-iliac

ligaments which are in two parts, one short and transverse, the other long and oblique (Fig. 79).

The Sacro-ischial Joint.—The ligaments of this joint bridge over the sacrosciatic notches, constructing foramina. The lesser sacrosciatic notch is crossed by the sacrotuberous ligament, the great sacrosciatic notch by the sacrospinous ligament. The sacrotuberous ligament is considered by some to be part of the tendon of the biceps muscle. It is roughly Y-shaped, a slip coming from the posterior inferior spine of the ilium and another from the sides and back of the sacrum to form a common stem, which makes a strong and firm band passing down to the inner margin of the ischial tuberosity and to part of the ascending ramus of the ischium, at which part it is called the falciform ligament. The sacrospinous ligament is in front of the sacrotuberous ligament and extends from the margins of the sacrum and coccyx to the ischial spine (Fig. 79).

The Symphysis Pubis.—This cartilaginous joint is also very important in midwifery and other pelvic conditions. There is a small pad of cartilage between the closely fitted portions of the pubic bones which are further bound together by anterior, posterior, superior and inferior pubic ligaments, the last filling up the angle of the pubis with its arching fibres.

Articulations of the Upper Extremity

The Sternoclavicular Joint.—In this joint the sternal end of the clavicle forms a gliding joint with the sternum and the cartilage of the first rib; there is an interarticular pad of cartilage. The movements possible are very restricted but take place in the upward, downward, forward and backward direction when necessary. In addition to the capsule formed by the anterior and posterior ligaments, there is an interclavicular ligament and a rhomboid portion which passes from the rough surface on the under aspect of the clavicle to the first rib.

The Scapuloclavicular Joint.—The acromial end of the clavicle is attached to the acromion process of the scapula by two stout bands enclosing a synovial membrane, called respectively the superior and inferior acromioclavicular ligaments. Another portion, the coracoclavicular ligament, has a lateral and a medial band, the former known as the trapezoid ligament and the latter as the conoid ligament (Fig. 80).

Ligaments of the Scapula.—The coracoacromial ligament forms an awning over the head of the humerus as it passes from the lateral border of the coracoid process to the tip of the acromion process. The suprascapular notch is converted into a foramen for the suprascapular nerve by a ligament which springs

from the base of the coracoid process—the transverse or suprascapular ligament (Fig. 80).

The Shoulder Joint.—Also known as the humeroscapular joint, this articulation is of supreme importance, since dislocations, fractures and other injuries are common at its site. It is a ball-and-socket joint, the round head of the humerus being received by the glenoid cavity of the scapula. Taking the joint from within first, we must note that it is plentifully supplied with synovia by membranes which are reflected on the tendons of various surrounding muscles; several bursae are also present.

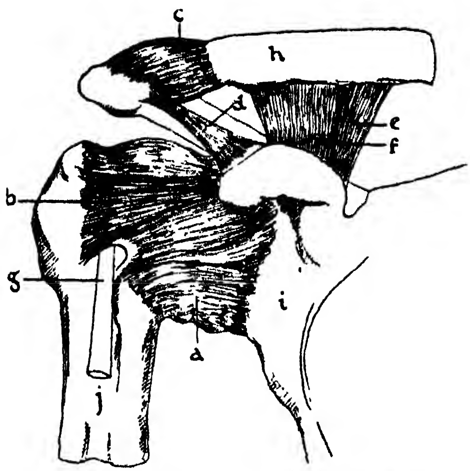


FIG. 80.—THE RIGHT SHOULDER JOINT AND THE SCAPULOCLAVICULAR JOINT. ANTERIOR ASPECT.

a, Capsular ligament. *b*, Coracohumeral ligament. *c*, Acromioclavicular ligament. *d*, Coracoacromial ligament. *e*, Coracoclavicular ligament, conoid part, *f*, Coracoclavicular ligament, trapezoid part. *g*, Tendon of biceps. *h*, Clavicle. *i*, Scapula. *j*, Humerus.

The glenoid ligament seems to be attached to the long head of the biceps muscle; the latter plays an important part in the joint, passing out of it by the bicipital groove which is bridged by the transverse ligament. This ligament consists of fibrocartilage, and is set like an elastic ring round the rim of the cavity, making the latter deeper and padding its edges. Two other ligaments are very intimately associated and they form the capsule of the joint, which is a very loose one, allowing free play of movement in every direction. The capsular ligament spreads from the margin of the glenoid cavity to the anatomical neck; the coracohumeral ligament arises in the coracoid process and runs to the greater tuberosity of the humerus. Thus the capsule is completed and we must have a clear conception of it as being capable of becoming slightly pleated when necessary, of being well lubricated and of being very loose, so that dislocation of the shoulder is not a difficult matter. Indeed, the bones of the shoulder are kept in position by the help of the strong muscles all round them (Fig. 80).

The Elbow Joint.—The bones involved in the hinge joint of the elbow are the humerus, radius and ulna. The radius articulates with the capitulum and the ulna with the trochlea. Usually the proximal radio-ulnar articulation is considered with the elbow joint, the whole being styled the cubital articulation. The articular capsule surrounds the joint, having a broad anterior part which is attached to the medial epicondyle and the front of

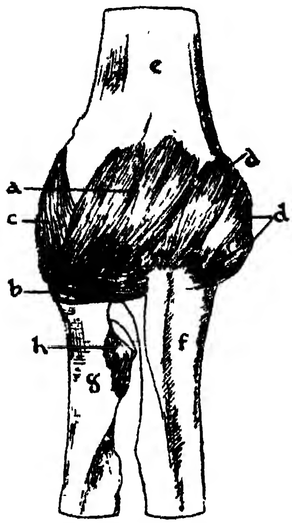


FIG. 81.—RIGHT ELBOW JOINT. ANTERIOR ASPECT.

a, Anterior capsular ligament. *b*, Annular ligament. *c*, Radial collateral ligament. *d*, Ulnar collateral ligament. *e*, Humerus. *f*, Ulna. *g*, Radius. *h*, Tendon of biceps.

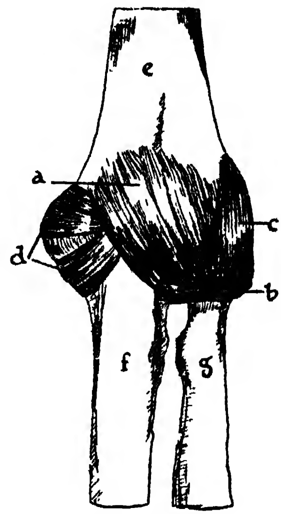


FIG. 82.—RIGHT ELBOW JOINT. POSTERIOR ASPECT.

a, Posterior capsular ligament. *b*, Annular ligament. *c*, Radial collateral ligament. *d*, Ulnar collateral ligament. *e*, Humerus. *f*, Ulna. *g*, Radius.

the humerus and to the annular ligament and the front of the coronoid process. The posterior part is thin and runs from a line passing across the humerus at the level of the margin of the olecranon fossa to the annular ligament, to the upper part of the olecranon process and to the ulna behind the radial notch. There are pads of fat in the capsule, which is lined by an extensive synovial membrane continued into the radio-ulnar joint. If we can imagine two strong lateral ligaments strengthening the capsule, we should have a clear conception of the two important collateral ligaments, radial and ulnar. The radial collateral (lateral) ligament is attached above to the lateral epicondyle and below

to the annular ligament; it is somewhat fan-shaped. The ulnar collateral (medial) ligament shows 3 distinct bands forming a triangle of strong tissue and connects the 3 points of the medial epicondyle, coronoid process and the medial margin of the olecranon process. The movements at this joint are flexion and extension, the radius and ulna moving as one bone on the end of the humerus (Figs. 81 and 82).

The Radio-ulnar Joints.—Although 2 radio-ulnar connections are usually recognized, 1 at the upper end and 1 at the lower end, there is a third in which the bones do not directly participate. Taking the last first, we find that it consists of two parts: 1. an interosseous membrane which forms a tissue screen, passing across from the radius to the ulna and for almost the whole length of the bones, setting up a division between the muscles on the front and on the back of the forearm; 2. an oblique cord passing from the coronoid process of the ulna to the radial shaft.

The Superior Radio-ulnar Joint.—The head of the radius pivots in the radial notch of the ulna and thus forms a trochoid joint of great interest. The head of the bone is kept in position by a flat annular band (the annular ligament) which almost completes a circle. Its free ends are fixed to the margins of the radial notch and to the lateral ligament. It gives off a few fibres from its lower edge to the neck of the radius—the quadrate portion.

The Inferior Radio-ulnar Joint.—This is also a pivot joint, the upper section of the wrist. The head of the ulna is set in the ulnar notch of the radius, the joint being enclosed in a capsule which is lined with synovial membrane. The two bones are bound together by a triangular articular disc which also forms a pad between the lower end of the ulna and the wrist joint.

Movements of the Radius and Ulna.—The radius moves so freely on the ulna that it can be used to turn the hand from front to back (pronation) and from back to front (supination). The muscles involved may be studied later; meanwhile it is well to appreciate the delicate adjustment of the rotation of the head of the radius at the upper end, with its wider sweep and greater arc at the lower end. In full pronation the radius forms a cross with the ulna; in supination the bones lie parallel. This is the mechanism which controls all the twisting movements of the hand. The ulna moves very little.

The Wrist Joint.—This is a radiocarpal joint, the bones involved being the radius, navicular, lunate and triquetral bones. It is a two-way joint. The triangular cartilage also takes part, assisting in the formation of an ovoid receiving cavity in which the convex surface of the carpus works. A capsule is formed by 4 distinct ligaments, anterior, posterior, lateral and medial, known

also as the volar radiocarpal ligament, the dorsal radiocarpal ligament, the radial collateral ligament and the ulnar collateral ligament respectively.

The wrist joint may be taken as an example of the way in which joints are naturally bound together. It is impossible to describe in full the various little strengthening bands which run in all directions from the 4 main fibrous sheets. It is very much akin to the work of a plumber when he mends an important pipe junction and keeps adding layer after layer of solder so that there is no possibility of weakness or leakage.

The movements are 5 in number—flexion, extension, abduction, adduction and a certain amount of circumduction.

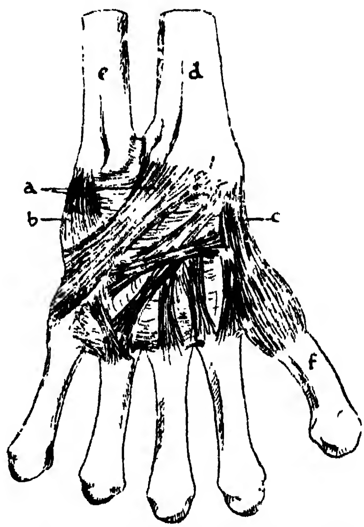


FIG. 83.—RIGHT WRIST JOINT AND CARPAL JOINTS. DORSAL ASPECT.

a, Dorsal radiocarpal ligament. *b*, Ulnar collateral ligament. *c*, Radial collateral ligament. *d*, Radius. *e*, Ulna. *f*, 1st metacarpal bone.

The Carpal Joints.—The proximal row of the carpus moves on the distal row but in addition to that the individual bones of each row articulate with their neighbours. There is a very extensive lining of synovial membrane allowing free lubrication everywhere of the gliding joints. The midcarpal joint, which is formed by the navicular, lunate and triquetral bones on one side, and by the greater multiangular, lesser multiangular, capitate and hamate on the other, is of the nature of a ball-and-socket joint at its centre, but the chief movements are flexion and extension. On the front of the hand the pisiform bone is connected to the hamate bone and to the 5th metacarpal bone by 2 distinct ligaments. Otherwise the bones are bound together by dorsal, palmar and interosseous ligaments. The midcarpal joint is strengthened by short collateral ligaments at the sides.

The Carpometacarpal Joints.—The 4 medial metacarpals form plane joints with the carpal facets above, and are kept in position by various palmar, dorsal and interosseous ligaments on a basis of capsular tissue. The movements at these joints are

very slight, but the little finger moves more freely than the rest. The thumb has a special saddle-shaped joint and is much wider in its range of movement. It is surrounded by a capsule lined by a synovial membrane. The movements permitted are flexion, extension, adduction, abduction, circumduction and a movement called opposition, which allows the fine movement of touching the tips of the fingers with the tip of the thumb.

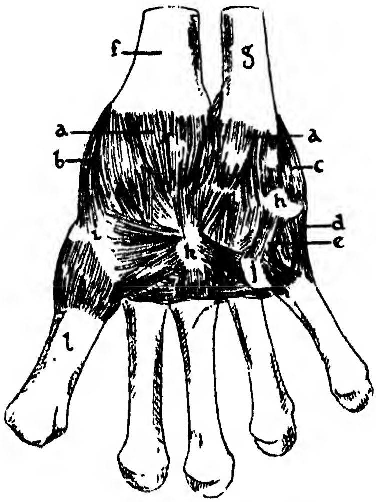


FIG. 84.—RIGHT WRIST JOINT AND CARPAL JOINTS. VOLAR ASPECT.

a, Volar radiocarpal ligament. *b*, Radial collateral ligament. *c*, Ulnar collateral ligament. *d*, Pisometacarpal ligament. *e*, Pisohamate ligament. *f*, Radius. *g*, Ulna. *h*, Pisiform. *i*, Greater multiangular. *j*, Hook of the hamate bone. *k*, Capitate. *l*, 1st metacarpal bone.

The Intermetacarpal Articulations are simple gliding joints at the bases of the bones, joined together by dorsal, palmar and interosseous ligaments.

The Metacarpophalangeal Joints.—Except for the thumb joint, which is akin to the ginglymus type, the metacarpal heads form condyloid joints with the phalangeal bases. The accessory volar ligaments are on the palmar aspect and are connected with the transverse metacarpal ligament, which runs like a band along the bases of the proximal phalanges. There are also collateral ligaments. The movements are flexion, extension, abduction and adduction.

The Interphalangeal Joints.—Each phalanx is bound to its neighbour by a palmar and two collateral ligaments. In place of the posterior ligaments are the extensor tendons. Flexion and extension are the only movements.

Articulations of the Lower Extremity

The Hip Joint.—With the head of the femur working in the deep cup of the acetabulum, the hip joint represents the biggest ball-and-socket joint of the body. There are 7 ligaments joining up the 2 bones. The cotyloid ligament, also known as the *labrum acetabulare*, is attached round the margin of the acetabulum,

and deepens it. The portion which crosses the notch at the inferior margin is specially named the transverse acetabular ligament. A foramen is thus formed through which pass vessels and nerves to the joint. Arising from 2 bands springing respectively from the margins of the acetabular notch and the transverse ligament is the stout, cord-like ligamentum teres, which is implanted into the head of the femur at the rough ovoid area already mentioned (Fig. 67, p. 74). This ligament is like a mooring rope, allowing the femur a certain amount of freedom within its limits. The capsule of the hip joint is strong and complete, enveloping the articular areas completely. It is attached to an area circumscribing the acetabulum, and surrounds the neck of the femur; it is much stronger in the front and above than behind and below. The capsule is strengthened by 3 auxiliary ligaments. The Y-shaped ligament of Bigelow, also referred to as the iliofemoral ligament, passes from the anterior inferior spine by two bands, one towards the greater trochanter and another to the lesser trochanter, the fibres being attached to the intertrochanteric line. The iliofemoral ligament gives added strength to the front of the capsule. The reinforcement behind is formed by the ischiofemoral ligament. Between these 2 ligaments, and forming an additional inferior portion of the capsule, is the pubofemoral ligament. The synovial membrane extends widely, covering the structures on the inside of the joint. Movements at the hip joint are flexion, extension, abduction, adduction, circumduction and rotation. The movements are somewhat complex; the capsule keeps the head of the femur close to the acetabulum, so that it is difficult to put the ball right out of the socket. The iliofemoral ligament is the strongest in the body; by its tension and toughness it maintains the body in

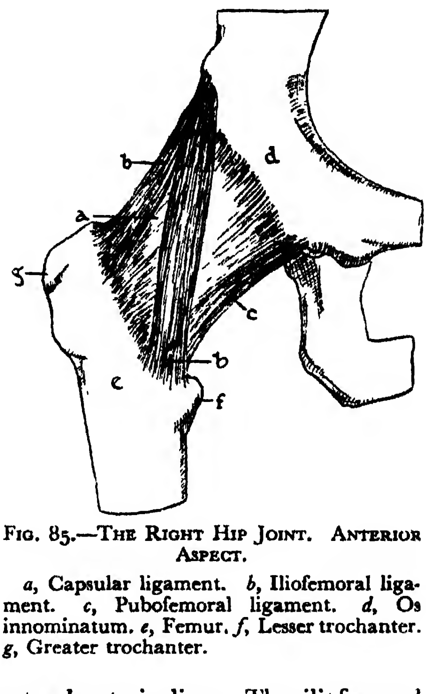


FIG. 85.—THE RIGHT HIP JOINT. ANTERIOR ASPECT.

a, Capsular ligament. *b*, Iliofemoral ligament. *c*, Pubofemoral ligament. *d*, Os innominatum. *e*, Femur. *f*, Lesser trochanter. *g*, Greater trochanter.

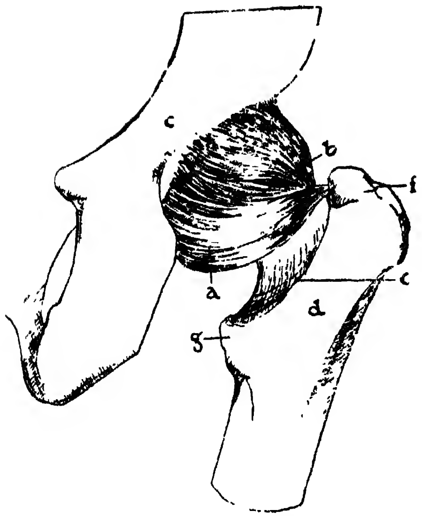


FIG. 86.—THE RIGHT HIP JOINT. POSTERIOR ASPECT.

a, Ischiofemoral ligament. *b*, Capsular ligament. *c*, Os innominatum. *d*, Femur. *e*, Intertrochanteric crest. *f*, Greater trochanter. *g*, Lesser trochanter.

the erect posture without putting a strain on the muscles.

The Knee Joint.—This joint demonstrates 3 distinct articulations—2 in which the femur and tibia take part, and 1 in which the patella and femur are concerned. Thus it combines two condyloid joints with a partially plane joint to form a hinge joint. Between the tibia and the femur are 2 menisci, also known as the medial and lateral semilunar cartilages. These are important pads of fibro-cartilage between the articular surfaces, and commonly give trouble to footballers and others by becoming loosened. On section these cartilages are wedge-shaped; they tend to deepen the articular cavity of the tibia. The medial meniscus is semicircular, but the lateral meniscus is almost a complete circle, and behind it gives off the ligament of Wrisberg a slip which is attached to the medial condyle of the femur. The knee joint is enclosed in a capsule which itself is thin, but which is so intimately bound up with the numerous surrounding and associated ligaments and tendons that it is very strong. The ligamentum patellae is really the

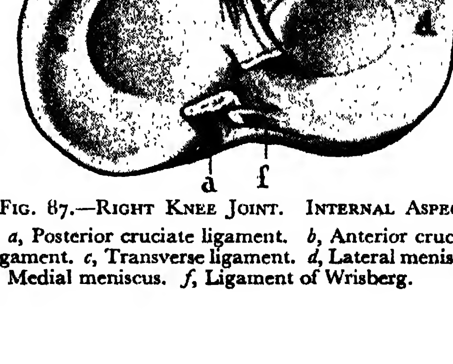


FIG. 87.—RIGHT KNEE JOINT. INTERNAL ASPECT.

a, Posterior cruciate ligament. *b*, Anterior cruciate ligament. *c*, Transverse ligament. *d*, Lateral meniscus. *e*, Medial meniscus. *f*, Ligament of Wrisberg.

continuation of the central portion of the quadriceps femoris muscle tendon; it extends from the patella to the tubercle of the tibia. The oblique popliteal (posterior) ligament is partly tendinous, being derived from the tendon of the semimembranosus muscle and from the capsular fibres below; above it is attached to the intercondyloid fossa. Below, and lateral to it, are a few strands called the arcuate popliteal ligament, which is associated with the lateral, or fibular collateral, ligament. The latter is the strong band which strengthens the outside of the knee and passes from the lateral condyle of the femur to the head of the fibula. The medial ligament, or tibial collateral, passes from the medial condyle of the femur, becomes firmly attached to the medial edge of the medial meniscus and ends on the medial surface of the shaft of the tibia. It is broad and flat, and maintains the contour of the inner aspect of the knee. The transverse ligament joins the two menisci in front; it is sometimes absent. The coronary ligaments act as a cement binding the head of the tibia to the edges of the menisci. Inside the joint, the 2 prominent cruciate ligaments, anterior and posterior, are very important, as they form a cross like the letter X and are instrumental in keeping the articular surfaces of the bones in approximation. The anterior cruciate ligament runs from the anterior intercondyloid fossa of the tibia to the medial aspect of the lateral condyle of the femur. The posterior cruciate ligament goes from the posterior condyloid fossa of the tibia to the lateral surface of the medial condyle of the femur.

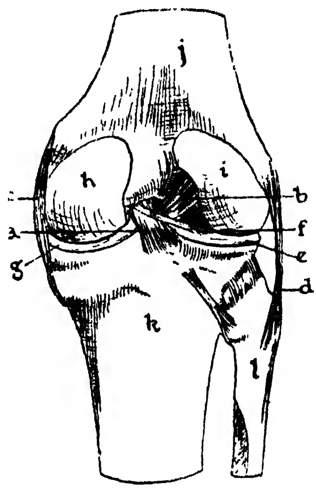


FIG. 88.—THE RIGHT KNEE JOINT. POSTERIOR ASPECT.

a, Posterior cruciate ligament. *b*, Anterior cruciate ligament. *c*, Medial ligament. *d*, Lateral ligament. *e*, Lateral semilunar cartilage. *f*, Ligament of Wrisberg. *g*, Medial semilunar cartilage. *h*, Medial condyle. *i*, Lateral condyle. *j*, Femur. *k*, Tibia. *l*, Fibula.

All the above ligaments ensure in an almost perfect, although somewhat complicated joint, the movements of flexion, extension and a certain amount of rotation. The position of the patella is such that it is a protective shield to the front of the knee joint and it also acts as a lever for the extensor muscles of the thigh. Lastly must be noted the synovial membrane, which is the largest and

most extensive in the body, forming several pads (or bursae) and various folds, and spreading over the anterior surface of the femur and the structures of the inside of the knee joint and under some of the tendons. One important bursa should be noted—that which forms a pad over the patella, and which is found inflamed and swollen in the condition known as " housemaid's knee."

The Tibiofibular Joints.—As in the arm, there is an interosseous membrane which joins the tibia to the fibular shaft for almost its entire length. At the upper part of this membrane the

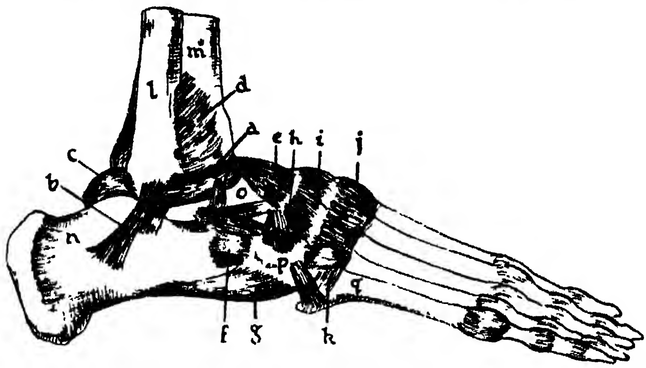


FIG. 89.—THE RIGHT ANKLE JOINT AND TARSAL JOINTS. LATERAL ASPECT.

a, Anterior talofibular ligament. *b*, Calcaneofibular ligament. *c*, Posterior talofibular ligament. *d*, Anterior ligament of inferior tibiofibular joint. *e*, Talonavicular ligament. *f*, Dorsal calcaneocuboid ligament. *g*, Long plantar ligament. *h*, Dorsal cuboideonavicular ligament. *i*, Dorsal cuneonavicular ligament. *j*, Tarsometatarsal ligaments. *k*, Intermetatarsal ligaments. *l*, Fibula. *m*, Tibia. *n*, Calcaneum. *o*, Talus. *p*, Cuboid. *q*, 5th metatarsal.

anterior tibial artery passes through, while at the lower end there is an opening for the peroneal artery. The superior tibiofibular joint is a plane joint with a synovial membrane, a capsule (which is thin behind) and an anterior and a posterior ligament. As already mentioned (p. 86), the inferior tibiofibular joint is a true example of a syndesmosis, the rough surfaces of the tibia and fibula being separated by very short but powerful strands of the interosseous ligament. There are 3 ligaments, an anterior, a posterior and a transverse, springing from the lateral malleolus, passing over the front and back of the joint, and spreading out to be fixed over the lower end of the tibia.

The Ankle Joint.—The bones entering into this joint are the lower end of the tibia, the medial malleolus, the lower end of the fibula, the lateral malleolus and the talus. It is a hinge joint of somewhat limited range. An anterior and a posterior ligament unite to form a firm capsule fixed to the tibia and talus in front

and behind. The medial (or deltoid) ligament is probably the most important of the ankle, as it is often torn. It arises at the medial malleolus and spreads out like a fan to be attached to the navicular, the talus and the calcaneum. The lateral ligament consists of an anterior, a middle and a posterior band of fibres. The anterior group is known as the anterior talofibular ligament, the middle as the calcaneofibular and the posterior as the posterior talofibular, their names indicating the bones associated with them. The movements are referred to as dorsiflexion (i.e. bringing the toes back towards the leg) and plantarflexion (pointing the toes as much as possible).

The Tarsal Joints.—The tarsal bones are firmly bound

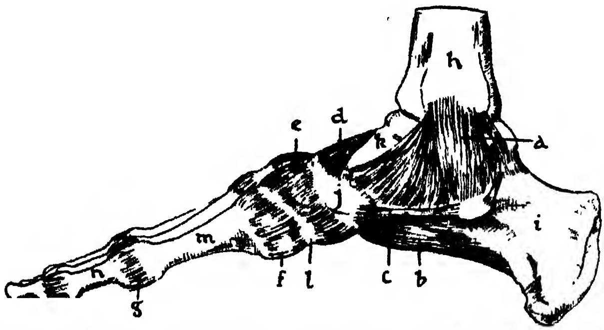


FIG. 90.—THE RIGHT ANKLE JOINT AND TARSAL JOINTS. MEDIAL ASPECT. *a*, Deltoid ligament. *b*, Long plantar ligament. *c*, Plantar calcaneonavicular ligament. *d*, Talonavicular ligament. *e*, Cuneonavicular ligament. *f and g*, Articular capsules. *h*, Tibia. *i*, Calcaneum. *j*, Navicular. *k*, Talus. *l*, 1st cuneiform. *m*, 1st metatarsal. *n*, 1st phalanx.

together in all directions by strong bands. The joints are all gliding joints, amply furnished with synovial fluid. The main articulations are described below.

The Talocalcaneal Joint.—This is also known as the calcaneo-astragaloid joint, and consists of a capsule, with anterior, posterior, medial and lateral ligaments connecting the calcaneum with the talus. There is an important interosseous ligament which is the main link between the bones and which is attached to the under surface of the talus and the upper surface of the calcaneum.

The Talocalcaneonavicular Joint.—This is a type of ball-and-socket joint. The head of the talus moves in the cavity formed by the navicular and calcaneum. It has an articular capsule and superiorly, the talonavicular ligament.

The movements of slight rotation and of gliding at the above two joints allow for eversion and inversion of the foot. Eversion means that the sole of the foot looks slightly outwards; inversion

means a raising of the inner border of the foot and an inclination of the sole inwards. These movements are limited by the action of the strong talocalcaneal interosseous ligament.

The Calcaneocuboid Joint.—The junction of the calcaneum and the cuboid bone is made by the articular capsule and by a dorsal ligament, a bifurcated ligament immediately above it sending slips to the cuboid and navicular bones; below are the plantar calcaneocuboid ligament (short plantar ligament) and the long plantar ligament. The last is the longest ligament of the tarsus; it is very strong and it is the main support of the lateral arch of the foot.

The Calcaneonavicular Connections.—There is no real articulation between the calcaneum and the navicular. The bifurcated ligament has already been described, and the remaining plantar calcaneonavicular ligament is the only other tie. This is a broad, thick ligament, supporting the head of the talus. It also supports the arch of the foot. The plantar calcaneonavicular ligament is also known as the spring ligament and is of supreme importance in flat foot.

Other Joints.—There are also ligaments joining the 3 cuneiform bones to the navicular—dorsal and plantar. The cuboid and navicular bones are united by dorsal, plantar and interosseous ligaments. The 3 cuneiform bones also are joined to the cuboid and to each other by dorsal and plantar ligaments, and by interosseous ligaments. The movements at all these joints are those of slight gliding only.

The Tarsometatarsal Joints.—These are very similar to the carpometacarpal joints. The 2nd metatarsal bone articulates with 3 cuneiform bones. The bones are united by plantar, dorsal and interosseous ligaments.

The Intermetatarsal Joints and the Metatarsophalangeal Joints are very similar to their representatives in the hand. The first phalanges are firmly attached on the plantar aspect to the neighbouring metatarsal by the accessory plantar ligaments. At each side is a collateral ligament.

The Phalangeal Joints.—The arrangement is similar to that in the fingers, the only movements being flexion and extension.

The Arches of the Foot.—The whole weight of the body is supported by the arches of the foot, the chief of which is the anteroposterior arch, divided into a medial arch and a lateral arch. There are also transverse arches, so that the sole of the foot represents part of a dome. The medial arch is formed by the bones of the medial half of the tarsus and metatarsus, and as mentioned above, is resilient and strong and well supported by the plantar calcaneonavicular ligament. Many muscles also take part. The lateral arch is constituted by the two lateral metatarsals, the calcaneum and cuboid; the long plantar ligament ensures its strength and rigidity.

CHAPTER 8

THE MUSCULAR SYSTEM

A TYPICAL MUSCLE. FASCIA. THE ACTION OF MUSCLES. VARIETIES OF MUSCLE. THE MUSCLES OF THE HEAD. MUSCLE OF THE SCALP. MUSCLES OF THE EAR. MUSCLES OF THE EYELIDS. MUSCLES OF THE ORBITAL REGION. MUSCLES OF THE NASAL REGION. MUSCLES OF THE MOUTH. CHEWING MUSCLES. THE MUSCLES OF THE NECK. MUSCLES OF THE LATERAL CERVICAL AREA. MUSCLES OF THE HYOID REGION. MUSCLES OF THE TONGUE. MUSCLES OF THE PHARYNX. MUSCLES OF THE PALATE. MUSCLES OF THE LARYNX AND THE EPIGLOTTIS. MUSCLES OF THE UPPER VERTEBRAL REGION. THE MUSCLES OF THE BACK. SUBOCCIPITAL MUSCLES. THE MUSCLES OF THE THORAX. THE DIAPHRAGM. THE MUSCLES OF THE ABDOMEN. THE MUSCLES OF THE ISCHIORECTAL REGION. THE PERINEAL MUSCLES. MUSCLES OF THE UPPER EXTREMITY. MUSCLES OF THE LOWER EXTREMITY. MUSCLES OF THE HIP. MUSCLES OF THE THIGH. THE FASCIA OF THE THIGH. MUSCLES OF THE LEG. MUSCLES OF THE FOOT. THE FASCIA OF THE FOOT.

MUSCLE as a tissue has already been described (pp. 17–18), and a knowledge has been gained of the microscopical features of muscle fibres and cells. There remains now to be made the investigation of the individual muscles and of the groups of muscles which form the fleshy parts of the body i.e. the striped muscles.

A Typical Muscle —Every muscle has an origin and an insertion. The origin is usually a roughened part or parts of a bone to which the fibres are firmly fixed. The insertion is the terminus of the muscle, generally represented by a small rough area on the bone to which the fibrous tendon of the muscle is attached. The belly of the muscle is the mass of flesh formed by millions of muscle fibres; it is usual for a muscle to taper gradually into the cord-like sinew or tendon, which is white and which contains much fibrous tissue. Muscles may also end in a glistening aponeurosis, which is a thinner and more widely distributed membrane but very strong and tough. Certain muscles terminate on the skin, in cartilage or in ligaments. A muscle may be flat (e.g. when

it is covering a large area like the chest) or rounded and long forming a sort of spindle (cf. the biceps or the calf muscles).

Fascia.—This tissue is widespread in the body, existing as thin layers of areolar tissue containing a variable amount of fibrous material, the whole forming a membrane which surrounds vessels, covers important organs and generally fills up odd corners and makes rough places smooth.

Superficial Fascia exists everywhere underneath the skin, binding the skin down and with its fat constituting a soft padded coat to the body as a whole. It is virtually a packing for the delicate nerves, blood vessels and other vital structures which lie superficially. The outer layer contains most of the fat and is therefore termed the panniculus adiposus. The panniculus carnosus is the name given to the deeper layer, which in some parts is muscular (cf. the platysma myoides). There is very little superficial fascia on the hands and feet, but a considerable amount in the groin and lower abdomen.

Deep Fascia is like an aponeurosis, being free of elastic tissue, dense, strong and fibrous. Usually it forms the sheaths of the muscles, but it may provide muscular attachments also. Often it binds together several muscles into a group, and when muscles are separated by dissection deep fascia is invariably discovered between them. Deep fascia also forms intermuscular septa. In some places (e.g. the palm of the hand) it is almost as strong as a thin layer of bone and is cut only with difficulty.

The Action of Muscles.—Since muscles are fixed at their origins and insertions, and since they have the power of contraction, it follows that the action of a muscle must be to bring the two points nearer to each other. This is accomplished through the medium of the joints, round which there are many muscular origins and insertions. It is a rule that when one extremity of a muscle moves, the other is for all practical purposes stationary, therefore the other extremity is pulled towards the fixed point. The action is very like that of a drawbridge. Generally speaking, the origin of the muscle is the superior attachment and moves very little, but the opposite can occur, as for example in the case of the biceps and the gluteus maximus; each of these may act with the pivot either at the origin or the insertion. In very few cases do muscles act alone; they are grouped in such a way that coordinated movement results in the performance of refined and accurate evolutions; when there is a group producing a certain type of movement (e.g. flexion) there is an antagonist group producing the opposite type of movement (e.g. extension). In the same way, adduction is opposite to abduction. The main action of each group depends upon the prime mover; when the latter contracts, its antagonists relax. Now to get the maximum effect

of this action, the origin of the muscle or group of muscles must be steadied and rendered almost immobile. This is done by the contraction of the fixation muscles which are like the wire stays or supporting posts of an ordinary crane. Similarly, when a muscle acts on a joint which may not be proximal to it, its fibres may pass over one or more intermediate joints, and if the action is to have its greatest efficiency a certain stiffening of these joints is essential. This is actually accomplished by certain muscles which are said to act as synergists. The boxer who tries to keep his adversary at arm's length knows that his closed fist is set on a poker-like arm, rigid at the elbow and wrist. All muscular action is governed by a nerve or nerves which send messages to its fibres like signals from a telegraph office; occasionally a group of muscles acts independently of the mind, the movement being made in a fraction of a second after some warning is given. This is known as reflex action and is discussed fully later on.

Varieties of Muscle.—In the muscular system we can nearly always tell the characteristics of the muscle by the name, which is indicative of its outstanding functions. For example the words, extensor, flexor, adductor, abductor, show what the muscle does; biceps, triceps, quadriceps indicate the number of heads; sterno-cleido-mastoid describes the attachments of the muscle; pyramidalis describes the shape of the muscle; brachialis anticus shows the site of the muscle; rectus femoris suggests direction of the fibres. Combinations of these names are frequently employed (e.g. pronator radii teres, which means a muscle which is round, and which turns the radius in the action of pronation). A muscle may be fusiform, quadrilateral or straplike; everything depends upon its main function. Sometimes cosmetic names are applied to muscles, such as the gracilis or the risorius.

The Muscles of the Head

In this group are included the muscles of the ears, the eyes, the nose, the mouth, the scalp and the face. Only the important ones are described at length. The illustrations have been carefully drawn in order to show clearly the essential features and thus long and meticulous description is considered to be unnecessary.

Muscle of the Scalp.—The occipitofrontalis (epicranius) muscle extends over the vault of the skull, from the nuchal lines to the eyebrows. An aponeurosis, the galea capitis, divides it into an occipital portion and a frontal portion at the vertex. It is supplied by the facial nerve, and its action is the raising of the eyebrow and the wrinkling of the forehead, associated with surprise and fright. The muscle also brings about movement of the entire scalp (Fig. 92).

Muscles of the Ear.—There are 3 extrinsic muscles of the ear—the auricularis superior, anterior and posterior respectively. They are supplied by the facial nerve and move the ears very slightly (Fig. 91).

Of the intrinsic muscles, 6 make up the pinna (see Fig. 91). These are all supplied by the facial nerve. Two muscles are

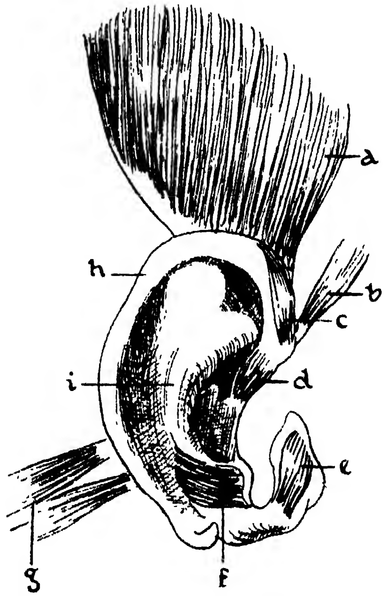


FIG. 91.—MUSCLES OF THE RIGHT EAR.

a, Auricularis superior m. *b*, Auricularis anterior m. *c*, Helicis major m. *d*, Helicis minor m. *e*, Tragicus m. *f*, Antitragicus m. *g*, Auricularis posterior m. *h*, Helix. *i*, Antihelix.

notable in the tympanum, and are described with the middle ear (p. 279).

Muscles of the Eyelids.—The orbicularis palpebrarum and the tensor tarsi muscles are parts of the orbicularis oculi, which surrounds the orbit and passes over the eyelids into the temporal region. Its main action is to close the eyelids. The tensor tarsi comes into full play in weeping, when it compresses the lacrimal sac. The corrugator supercilii draws the eyebrow downwards and inwards, producing wrinkling of the skin of the forehead—the furrowed brow familiar in frowning. All these muscles are supplied by the seventh cranial nerve (Fig. 92).

Muscles of the Orbital Region.

Name.	*Action.*	*Nerve.*	*Remarks.*
Levator palpebrae superioris	Raises upper lid	Motor oculi	Inserted into upper tarsal cartilage
Rectus superior	Rotates eyeball upwards	Ditto	Inserted into sclerotic
Rectus inferior	Rotates eyeball downwards	Ditto	Ditto
Rectus medialis	Rotates eyeball medially	Ditto	Ditto
Rectus lateralis	Rotates eyeball laterally	Abducens	Ditto
Superior oblique	Rotates eyeball on horizontal axis	Trochlear	Arises at edge of optic foramen. Tendon passes through a pulley and is inserted into sclerotic
Inferior oblique	Ditto	Motor oculi	From orbital plate of maxilla into sclerotic

The levator palpebrae superioris arises from the lesser wing of the sphenoid; all the recti muscles arise from a common tendinous ring round the orbit, the upper part of which is known as the ligament of Lockwood and the lower as the ligament of Zinn.

Muscles of the Nasal Region.—Five muscles properly belong to this region, all supplied by the facial nerve. Their actions are to dilate and to contract the nostrils and to give expression to the areas close to the nose. The muscles are the pyramidalis nasi (or procerus) the dilatores naris (anterior and posterior) the compressor (or nasalis) and the depressor alae nasi (or depressor septi).

Muscles of the Mouth.—Nine muscles are involved in the movements and structure of the mouth and of the tissues in its immediate vicinity, all supplied by the facial nerve (Fig. 92)

1. *Quadratus labii superioris.*—This muscle can be split up into 3 heads—the infra-orbital, which passes from the lower margin of the orbit to the upper lip, and is sometimes known as the levator labii superioris; the zygomatic, which springs from the zygomatic process and which raises the lip laterally; and the angular, which passes down from the frontal process of the maxilla and splits into two, well described by its old name of

levator labii superioris alaeque nasi. These 3 portions acting together produce a look of contempt.

2. *Levator anguli oris.*—Also known as the caninus.

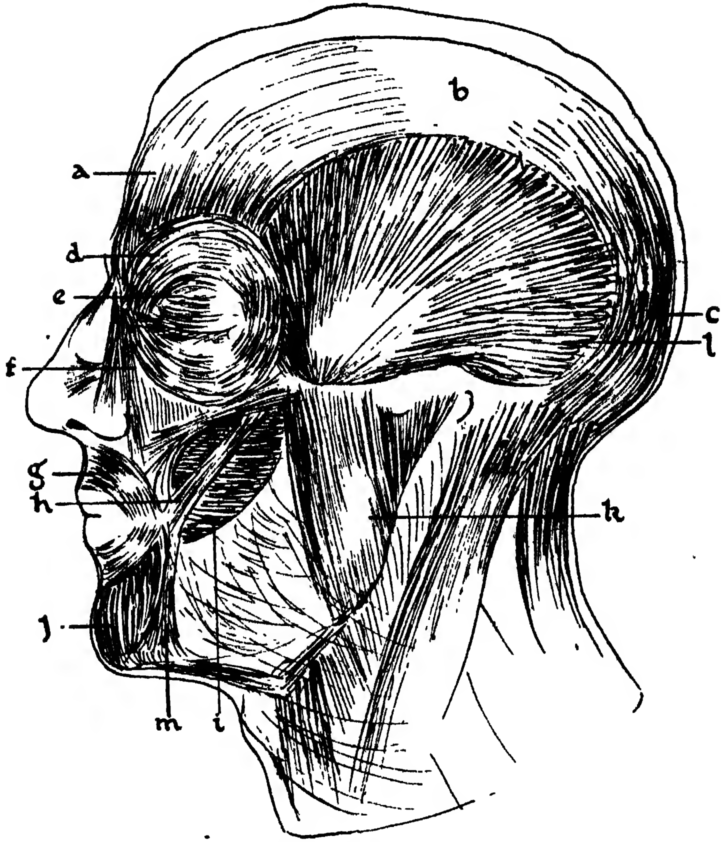


Fig. 92.—Muscles of the Scalp and Face. Left Lateral Aspect.

a, Occipitofrontalis m., frontal part. *b*, Galea capitis. *c*, Occipitofrontalis m., occipital part. *d*, Orbicularis oculi m., orbital part. *e*, Orbicularis oculi m., palpebral part. *f*, Quadratus labii superioris m. *g*, Orbicularis oris m. *h*, Zygomaticus m. *i*, Buccinator m. *j*, Depressor labii inferioris m. *k*, Masseter m. *l*, Temporal m. *m*, Depressor anguli oris m.

3. *Zygomaticus.*—Raises the lip laterally at the angle of the mouth.

4. *Mentalis.*—The fibres run from the incisive fossa to the skin of the chin. Raises and protrudes the lower lip.

5. *Depressor labii inferioris.*—Inserted into lower lip, which it depresses. Arises in the oblique mandibular line.

6. *Depressor anguli oris.*—Arises as above; goes to angle of the mouth which it depresses.

7. *Orbicularis oris.*—This muscle closes the mouth. The fibres do not form a circular band round the lips, but run in 2 bundles, the superior and inferior incisive bundles, which blend with the buccinator muscle.

8. *Buccinator.*—This muscle arises from the alveolar processes of the maxilla and mandible, forming the walls of the mouth; the fibres pass into the orbicularis oris. The parotid duct passes through it. Its action is to compress the cheeks, and it is the muscle seen in the action of whistling or of blowing a trumpet.

9. *Risorius.*—This, the muscle of laughter, retracts the angle of the mouth.

Chewing Muscles.—There are 4 chewing muscles, all supplied by the mandibular nerve (Fig. 92).

Name.	*Origin.*	*Insertion.*	*Action, etc.*
Masseter	Zygomatic arch	Lateral surface of angle and ramus of mandible	Raises jaw. Masticates food
Temporal	Temporal fossa and fascia	Coronoid process of mandible	Brings incisors together; used in biting. Looks like a large feather
Lateral pterygoid	(*a*) Greater wing of sphenoid. (*b*) Lateral pterygoid lamina	Condyle of the mandible and articular cartilage	Protrudes lower jaw
Medial pterygoid	Palate, and lateral pterygoid lamina	Medial surface of angle and ramus of lower jaw	Assists in side-to-side movements of jaw, triturating the food

The Muscles of the Neck

This group comprises the muscles of the front and sides of the neck, of the tongue, pharynx and palate, and those deeply placed in front of the upper part of the spine.

Muscles of the Lateral Cervical Area (Fig. 93).

1. *Platysma myoides.*—This muscle has already been mentioned as the panniculus carnosus of the superficial fascia. It arises

from the fascia covering the deltoid and pectoralis major muscles, and sweeps up to the skin over the lower jaw, the angle of the mouth and the cheeks. It is supplied by the facial nerve, and it acts by wrinkling the neck and drawing down the angle of the mouth.

2. *Sterno-cleido-mastoid.*—This is a very important and pro-

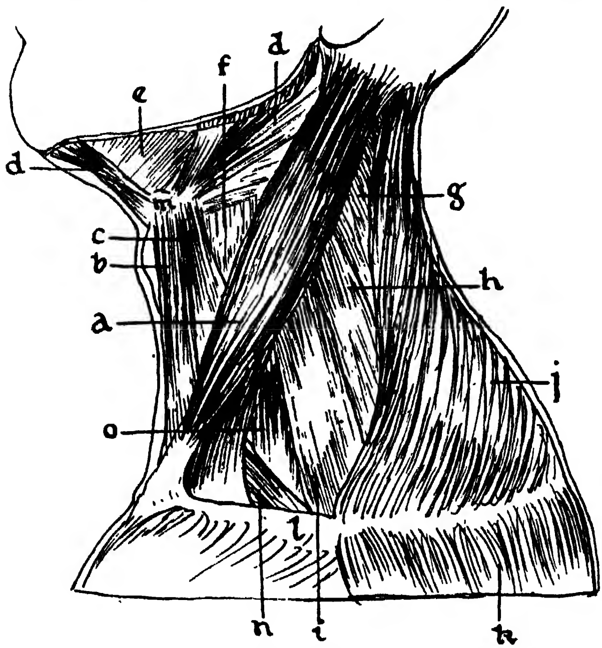


FIG. 93.—MUSCLES OF THE NECK. LEFT LATERAL ASPECT.

a, Sterno-cleido-mastoid m. *b*, Sternohyoid m. *c*, Omohyoid m. sup. *d*, Digastricus m. *e*, Mylohyoid m. *f*, Thyrohyoid m. *g*, Splenius capitis m. *h*, Levator scapulae m. *i*, Scalenus medius m. *j*, Trapezius m. *k*, Deltoid m. *l*, Clavicle. *m*, Hyoid bone. *n*, Omohyoid m. inf. *o*, Scalenus anterior m.

minent muscle, which can easily be seen and felt running obliquely across the neck from its origins at the sternum and clavicle to its insertions at the mastoid process and the superior nuchal line. It divides the neck into the anterior and posterior triangles. Its nerve is the XI cranial, or accessory, which crosses it about the middle. This muscle flexes the head when working with its fellow; the individual muscles draw the head towards the shoulder and also rotate the face to the opposite side. Paralysis of one muscle causes the condition of wryneck.

Muscles of the Hyoid Region.—These can be divided into a group of 4 above the hyoid bone, and a group of 4 below the hyoid bone (Fig. 93).

SUPRAHYOID REGION

Name.	*Origin.*	*Insertion.*	*Action and Nerve Supply.*
Digastric	1. Mastoid process of temporal bone (posterior belly). 2. Inner aspect of mandibular symphysis (anterior belly)	The two bellies meet at a central tendon which is bound down by a fascial slip to the hyoid bone	Raises the tongue and hyoid bone. Nerve supply: Posterior belly, facial: Anterior belly, inferior dental nerve
Stylohyoid	Base of styloid process of temporal bone	Body of hyoid bone	Moves hyoid bone. Supplied by facial nerve. Perforated by digastric
Mylohyoid	Mylohyoid line of mandible	Front of hyoid bone. Median *raphé* between mandible and hyoid	Raises hyoid bone. Forms floor of mouth. Supplied by inferior dental nerve
Geniohyoid	Mental spines of mandible	Body of hyoid	Same as mylohyoid. Nerve supply: hypoglossal nerve

INFRAHYOID REGION

Name.	*Origin.*	*Insertion.*	*Action and Nerve Supply.*
Sternohyoid	Sternum and clavicle	Body of hyoid	Depresses hyoid. Nerve supply: hypoglossal
Sternothyroid	Sternum and first rib	Thyroid cartilage	Lies under the above. Draws down larynx. Supplied by hypoglossal nerve
Thyrohyoid	Thyroid cartilage	Hyoid bone	Depresses larynx and hyoid. Supplied by hypoglossal nerve
Omohyoid	Scapula: upper border	Hyoid bone	Has a central tendon bound down by fascia to first rib and clavicle, thus forming a superior and inferior belly. Nerve: hypoglossal

from the fascia covering the deltoid and pectoralis major muscles, and sweeps up to the skin over the lower jaw, the angle of the mouth and the cheeks. It is supplied by the facial nerve, and it acts by wrinkling the neck and drawing down the angle of the mouth.

2. *Sterno-cleido-mastoid.*—This is a very important and pro-

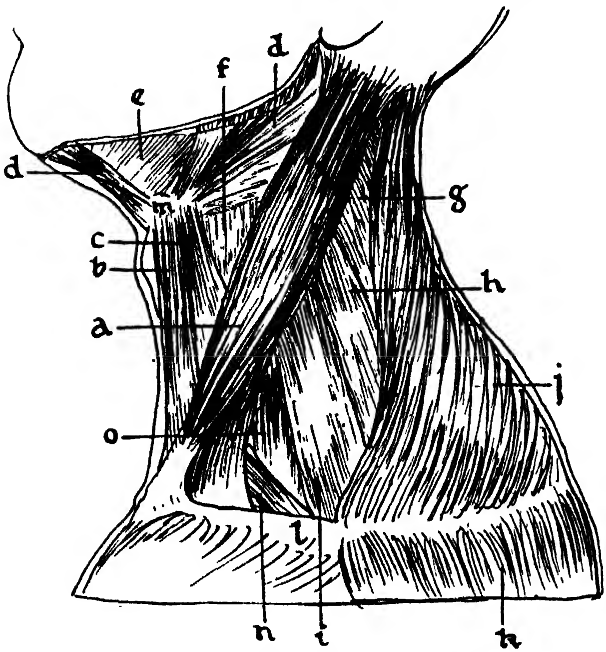


FIG. 93.—MUSCLES OF THE NECK. LEFT LATERAL ASPECT.

a, Sterno-cleido-mastoid m. *b*, Sternohyoid m. *c*, Omohyoid m. sup. *d*, Digastricus m. *e*, Mylohyoid m. *f*, Thyrohyoid m. *g*, Splenius capitis m. *h*, Levator scapulae m. *i*, Scalenus medius m. *j*, Trapezius m. *k*, Deltoid m. *l*, Clavicle. *m*, Hyoid bone. *n*, Omohyoid m. inf. *o*, Scalenus anterior m.

minent muscle, which can easily be seen and felt running obliquely across the neck from its origins at the sternum and clavicle to its insertions at the mastoid process and the superior nuchal line. It divides the neck into the anterior and posterior triangles. Its nerve is the XI cranial, or accessory, which crosses it about the middle. This muscle flexes the head when working with its fellow; the individual muscles draw the head towards the shoulder and also rotate the face to the opposite side. Paralysis of one muscle causes the condition of wryneck.

Muscles of the Hyoid Region.—These can be divided into a group of 4 above the hyoid bone, and a group of 4 below the hyoid bone (Fig. 93).

SUPRAHYOID REGION

Name.	*Origin.*	*Insertion.*	*Action and Nerve Supply.*
Digastric	1. Mastoid process of temporal bone (posterior belly). 2. Inner aspect of mandibular symphysis (anterior belly)	The two bellies meet at a central tendon which is bound down by a fascial slip to the hyoid bone	Raises the tongue and hyoid bone. Nerve supply: Posterior belly, facial: Anterior belly, inferior dental nerve
Stylohyoid	Base of styloid process of temporal bone	Body of hyoid bone	Moves hyoid bone. Supplied by facial nerve. Perforated by digastric
Mylohyoid	Mylohyoid line of mandible	Front of hyoid bone. Median *raphé* between mandible and hyoid	Raises hyoid bone. Forms floor of mouth. Supplied by inferior dental nerve
Geniohyoid	Mental spines of mandible	Body of hyoid	Same as mylohyoid. Nerve supply: hypoglossal nerve

INFRAHYOID REGION

Name.	*Origin.*	*Insertion.*	*Action and Nerve Supply.*
Sternohyoid	Sternum and clavicle	Body of hyoid	Depresses hyoid. Nerve supply: hypoglossal
Sternothyroid	Sternum and first rib	Thyroid cartilage	Lies under the above. Draws down larynx. Supplied by hypoglossal nerve
Thyrohyoid	Thyroid cartilage	Hyoid bone	Depresses larynx and hyoid. Supplied by hypoglossal nerve
Omohyoid	Scapula: upper border	Hyoid bone	Has a central tendon bound down by fascia to first rib and clavicle, thus forming a superior and inferior belly. Nerve: hypoglossal

Muscles of the Tongue.—The muscles of the tongue consist of 4 which are in the substance of the tongue (intrinsic) and 5 which are concerned with the movement of the tongue as a whole (extrinsic).

Intrinsic Muscles.—The muscles form 4 layers, the fibres of which pass forwards and outwards, transversely and vertically; some of the extrinsic muscles of the tongue blend with the intrinsic muscles. These muscles give shape to the tongue and form its substance; they are supplied by the hypoglossal nerve.

Extrinsic Muscles.—Four of the tongue muscles are tabulated below; the 5th is the palatoglossus, usually considered with the muscles of the palate.

Name.	*Origin.*	*Insertion.*	*Action.*
Genioglossus	Mental spines of mandible	Under surface of tongue; hyoid bone; pharynx	Protrudes tongue
Hyoglossus	Cornu of hyoid	Side of tongue	Draws side of tongue down
Chondro-glossus	Hyoid bone	Between genio-glossus and hyo-glossus	As above
Styloglossus	Styloid process	Side of tongue	Raises tongue

The above muscles are supplied by the hypoglossal (XII) nerve.

Muscles of the Pharynx.—The pharyngeal muscles consist first of 3 constrictor muscles—upper, middle and lower—which by contraction force the food from the back part of the mouth into the gullet. They arise, respectively, from the sphenoid, palate bone, lower jaw and tongue; hyoid bone and stylohyoid ligament; and laryngeal cartilages; and are inserted at various levels into the fibrous *raphé* at the back of the pharynx. The nerve supply comes from the pharyngeal plexus. One other muscle may be taken with this group, the stylopharyngeus, which begins at the styloid process and ends in the fibres of the constrictor muscles and on the thyroid cartilage; its nerve is the glossopharyngeal and its action is to raise the pharynx. The physiology of swallowing is discussed later (pp. 217-218), but it is well to note here that the upper part of the alimentary tube is surrounded by a deep collar of muscles which in concert seem to act as a valve for the gullet.

Muscles of the Palate.—There is such a close connection

between the muscles of the tongue, pharynx and palate that it is not easy to group them. Of the muscles mentioned below, the palatoglossus partly belongs to the tongue and the palatopharyngeus partly to the pharynx. With the exception of the tensor palati, which is supplied by the mandibular nerve, all the muscles are supplied by the pharyngeal plexus of the spinal accessory nerve.

1. *Levator palati.*—This arises in the petrous portion of the temporal bone and the pharyngo-tympanic (Eustachian) tube, and ends in the soft palate behind, which it elevates.

2. *Tensor palati.*—This starts at the spine of the sphenoid and arises also from the pharyngo-tympanic tube; it is bent round the hamulus and terminates in the soft palate and the palate bone (horizontal portion). It keeps the soft palate tense.

3. *Azygos uvulae.*—This is a small slip of muscle which raises the uvula and which has origin at the posterior nasal spine and the soft palate.

4. *Palatoglossus.*—This forms the anterior pillar of the fauces (palatoglossal arch).

5. *Palatopharyngeus.*—This forms the posterior pillar of the fauces (palatopharyngeal arch). It also closes the posterior nares.

6. *Salpingopharyngeus.*—The salpingopharyngeus muscle is connected with the palatopharyngeus at its insertion. It arises near the orifice of the pharyngo-tympanic tube, its action being the raising of the upper part of the pharynx.

Muscles of the Larynx and Epiglottis.—These are described more conveniently with the respiratory system (p. 188).

Muscles of the Upper Vertebral Region.

IN FRONT

Name.	*Origin.*	*Insertion.*	*Action and Nerve Supply.*
Longus capitis	3rd to 6th cervical vertebrae	Basi-occipital	Flexes and rotates head. Nerves: 1st, 2nd, 3rd and 4th cervical
Rectus capitis anterior	Atlas	Ditto	1st and 2nd cervical
Rectus capitis lateralis	Atlas	Jugular process	Bends head to the side. Nerve supply as above

IN FRONT (*continued*)

Name.	*Origin.*	*Insertion.*	*Action and Nerve Supply.*
Longus cervicis: (*a*) *superior oblique*	3rd, 4th and 5th cervical vertebrae (transverse processes)	Atlas	Flexes neck
(*b*) *inferior oblique*	Bodies of 1st, 2nd and 3rd dorsal vertebrae	5th and 6th cervical (transverse processes)	Flexes and rotates the cervical region of spine
(*c*) *vertical*	Bodies of 5th, 6th and 7th cervical; 1st, 2nd and 3rd dorsal vertebrae	Bodies of 2nd, 3rd and 4th cervical	Supplied by the lower cervical nerves

AT THE SIDES

Name.	*Origin.*	*Insertion.*	*Action and Nerve Supply.*
Scalenus anterior	3rd to 6th cervical vertebrae (transverse processes)	1st rib (scalene tubercle)	Bends neck to side; may raise thorax. Nerves: 4th, 5th, 6th cervical
Scalenus medius	Transverse processes of lower 6th c. vertebrae	1st rib	Ditto
Scalenus posterior	Transverse processes of 6th, 7th c. vertebrae	2nd rib	Ditto

The Muscles of the Back

Most of the muscles of the back are thin muscles, although some become more rounded towards their insertions. The best way to understand their arrangement is to regard the musculature of the back as consisting of a series of thin layers, 7 of which may be recognized as under:

First Layer: Trapezius; Latissimus dorsi.

Second Layer: Levator scapulae; Rhomboideus minor; Rhomboideus major.

The above layers are known as the appendicular group, since they are connected with the arm.

Third Layer:	Serratus posterior superior. Serratus posterior inferior.
Fourth Layer:	Splenius capitis. Splenius cervicis.
Fifth Layer:	The Erector spinae mass, divided into 2 masses: (*a*) The Sacrospinal mass; (*b*) The Semispinal mass.
Sixth Layer:	Multifidus spinae. Rotatores spinae.
Seventh Layer:	Interspinales. Intertransversales.

The above 5 layers are the axial group, connected with the skull, vertebrae, ribs and pelvis. In front of the 4th layer is the vertebral aponeurosis, a fascial layer which invests the 5th, 6th and 7th layers.

The Suboccipital group of muscles is taken separately.

Layer 1 (Fig. 94).—*Trapezius.*—The upper part of this muscle belongs to the cervical region, but the muscle is best treated as a whole. It is a great fleshy triangle, based on the middle line, with its apex running out towards the point of the shoulder. The origin extends from the occipital bone to the ligamentum nuchae, the spines of the last cervical and all the thoracic vertebrae: the insertion is the lateral end of the clavicle, the acromion process and the spine of the scapula. This muscle keeps the shoulders back and the head erect; it controls generally the poise of the head and neck. Its nerve supply is the spinal accessory nerve (XI cranial) and a branch of the cervical plexus.

Latissimus dorsi.—At its origin, this muscle is overlapped by the trapezius, which in shape and character it resembles very much. It begins as an aponeurosis springing from the spines of the 7th to 12th dorsal vertebrae, of the lumbar vertebrae, and of the sacral vertebrae, the crest of the ilium and the 10th to 12th ribs, which gives place to a large fleshy mass converging into a rounded termination ending in a flat tendon inserted into the bicipital groove of the humerus. Its nerve supply is the nerve to the latissimus dorsi. The action of this muscle is to pull the arm backwards and downwards; it may also elevate the lower part of the thorax.

Layer 2.—*Levator scapulae.*—As its name implies, this muscle raises the upper angle of the scapula, into the vertebral border

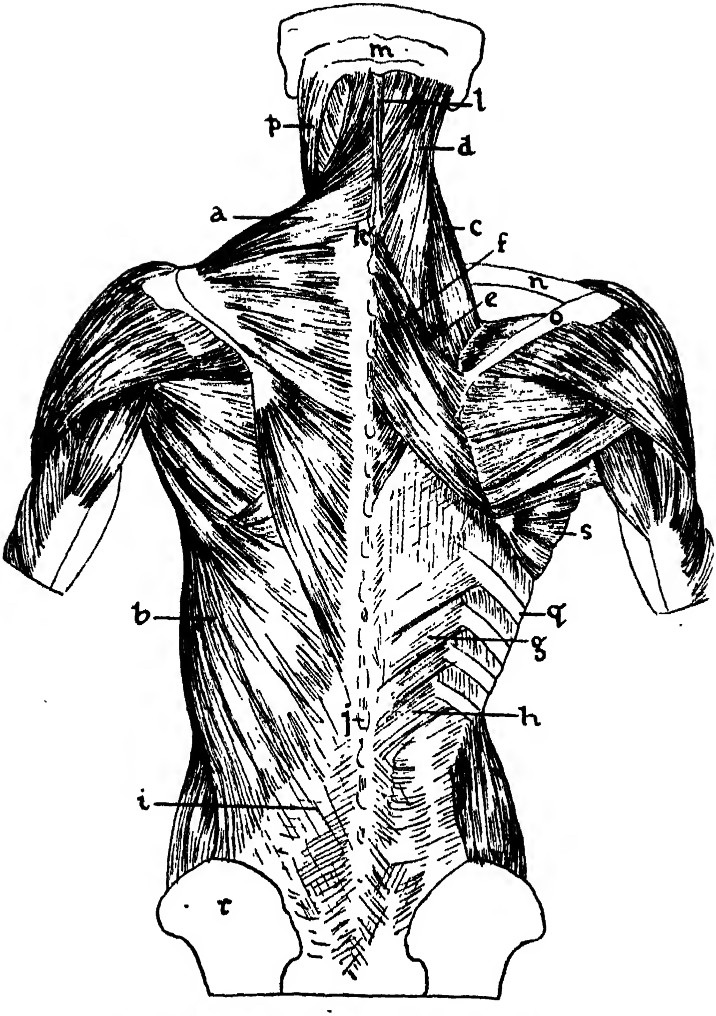


FIG. 94.—MUSCLES OF THE BACK. SHOWING LAYERS 1, 2, 3, 4.

a, Trapezius m. *b*, Latissimus dorsi m. *c*, Levator scapulae m. *d*, Splenius capitis and cervicis mm. *e*, Rhomboideus minor m. *f*, Rhomboideus major m. *g*, Serratus posterior inferior m. *h*, Edge of vertebral fascia. *i*, Lumbar fascia. *j*, 12th thoracic vertebra. *k*, 7th cervical vertebra. *l*, Ligamentum nuchae. *m*, Occipital bone. *n*, Clavicle. *o*, Spine of scapula. *p*, Sterno-cleido-mastoid m. *q*, 9th rib. *r*, Ilium. *s*, Serratus anterior m.

of which it is inserted. It springs from the transverse processes of the 4 upper cervical vertebrae by distinct slips and is supplied by the 3rd, 4th and 5th cervical nerves (Fig. 94).

Rhomboideus minor.—This muscle lies with its partner under the trapezius and runs obliquely downwards and laterally to the root of the scapular spine. It begins in the ligamentum nuchae, and the spines of the last cervical and first dorsal vertebrae. It helps to suspend the scapula, drawing it backwards and upwards. It is supplied by the 5th cervical nerve.

Rhomboideus maior.—This muscle has the same action and the same nerve supply as the above. Its origin is generally the spines of the 2nd to 5th dorsal vertebrae, and it is inserted by a tendon into the vertebral border of the scapula at a line extending from the root of the spine to the inferior angle.

Layer 3.—*Serratus posterior superior.*—The serrati group is most important, since the muscles are vital in respiration, the superior raising the ribs and the inferior depressing them, both thus expanding and contracting the thoracic space. The serratus superior originates in the ligamentum nuchae and the spines of the 7th cervical and the 1st and 2nd dorsal vertebrae, after which it splits up into 4 slips which are attached respectively to the upper borders of the 2nd to 5th ribs. It is supplied by branches of the upper dorsal nerves (Fig. 94).

Serratus posterior inferior.—This muscle runs upwards and outwards from the spines of the 11th and 12th dorsal and the 1st, 2nd and 3rd lumbar vertebrae, and is attached by 4 tags to the lower 4 ribs. The nerve supply is provided by the lower thoracic nerves.

Layer 4.—*Splenius.*—It is convenient to take the splenius muscles together. Partly covered by the rhomboid muscles, these muscles run almost vertically upwards, beginning in the ligamentum nuchae and the last cervical and first 6 dorsal spines, and ending (as the splenius capitis) in the region of the mastoid process, and (as the splenius cervicis) in the transverse processes of the 3 upper cervical vertebrae. These muscles help to keep the neck stiff and to draw back the head. They are supplied by the cervical nerves (Fig. 94).

Layer 5.—In dealing with the 5th layer, it is necessary to split up further the group into divisions which are self-evident. The muscles are characteristically long and ribbon-like, akin to the stays of a tall mast, and their action is generally to maintain the spine in the erect posture. The erector spinae, or sacrospinalis, originates in the iliac crest, sacro-iliac groove and the lumbosacral tendon, dividing into the iliocostal and longissimus muscles, which are included in the table given below.

Table showing the Muscles of the Fifth Layer by Divisions

ILIOCOSTAL DIVISION

Name.	*Origin.*	*Insertion.*
1. *Iliocostalis lumborum*	Continuation of erector spinae	Angles of lower 7 ribs
2. *Iliocostalis dorsi*	Angles of lower 6 ribs	Angles of upper 6 ribs
3. *Iliocostalis cervicalis*	Angles of upper 5 ribs	Transverse processes of 4th, 5th and 6th cervicals

LONGISSIMUS DIVISION

Name.	*Origin.*	*Insertion.*
1. *Longissimus thoracis*	Main mass of erector spinae	Transverse processes of thoracic and lumbar vertebrae, 3rd to 11th ribs near angle
2. *Longissimus cervicis*	Transverse processes, 1st to 6th dorsal vertebrae	Transverse processes, 2nd to 6th cervical vertebrae
3. *Longissimus capitis*	Transverse processes, 1st to 6th dorsal; larticular processes 4th to 7th cervical vertebrae	Mastoid process

SPINAL DIVISION

Name.	*Origin.*	*Insertion.*
1. *Spinalis thoracis*	11th and 12th dorsal; 1st and 2nd lumbar spines	1st to 8th dorsal spines (variable)
2. *Spinalis cervicis* (often missing)	5th, 6th and 7th cervical spines	Spine of axis

SEMISPINAL MASS

Name.	*Origin.*	*Insertion.*
1. *Semispinalis thoracis*	Transverse processes of 5th to 11th dorsal vertebrae	6th and 7th cervical; 1st to 4th dorsal spines
2. *Semispinalis cervicis*	Transverse processes of 1st to 6th dorsal vertebrae	2nd to 5th cervical spines
3. *Semispinalis capitis* (*Complexus*); (including *biventer cervicis*)	Transverse processes, 7th cervical and 1st 6 dorsal vertebrae; articular processes of 4th, 5th and 6th cervical	Interval between nuchal lines of occipital bones

All the muscles of the 5th layer perform some part in keeping the spine erect at various levels. They also bend the trunk backwards. The complexus rotates the head in addition to retracting it. The spinalis cervicis keeps the neck steady, in which it is assisted by the longissimus cervicis and the longissimus capitis.

Layer 6.—*Multifidus spinae.*—This is one of the lower lumbar muscles, supplied by the spinal nerves; it helps to maintain the spine firmly at the lumbar region and otherwise rotates the spine and keeps it erect. The fibres begin on the back of the sacrum and at the posterior sacro-iliac ligaments, and from one end of the column to the other, the muscle is represented by slips which pass from the articular processes of the lumbar vertebrae, the transverse processes of the dorsal vertebrae and the articular processes of the 4th to 7th cervical vertebrae into the spines of the 4 vertebrae immediately above.

Rotatores spinae.—As their name implies, the rotatores rotate the spinal column, their nerve supply being the posterior thoracic. Successive slips of muscle pass from the transverse processes of all the dorsal vertebrae (except the 1st) into the lamina of the bone immediately above.

Layer 7.—*Interspinales.*—These muscles are in pairs and pass from the spine of one vertebra to the spine of the next, there being about 12 pairs in all.

Intertransversales.—Slips of muscle join the transverse processes on either side along the vertebral column, there being in all 23 muscular tags.

Extensor coccygis is a small muscle running along the posterior part of the coccyx.

Suboccipital Muscles.—This is a group of small muscles 4 in number, passing outwards to the base of the skull and the neighbouring vertebrae from the middle line. The nerve supply is provided by the 1st cervical nerve.

Name.	*Origin.*	*Insertion.*
1. *Rectus capitis posterior major*	Spine of axis	Inferior nuchal line of occipital and at area below it
2. *Rectus capitis posterior minor*	Tubercle on posterior arch of atlas	An area immediately lateral to foramen magnum
3. *Obliquus capitis inferior*	Spinous process of axis	Transverse process of axis
4. *Obliquus capitis superior*	Transverse process of atlas	An area between the nuchal lines

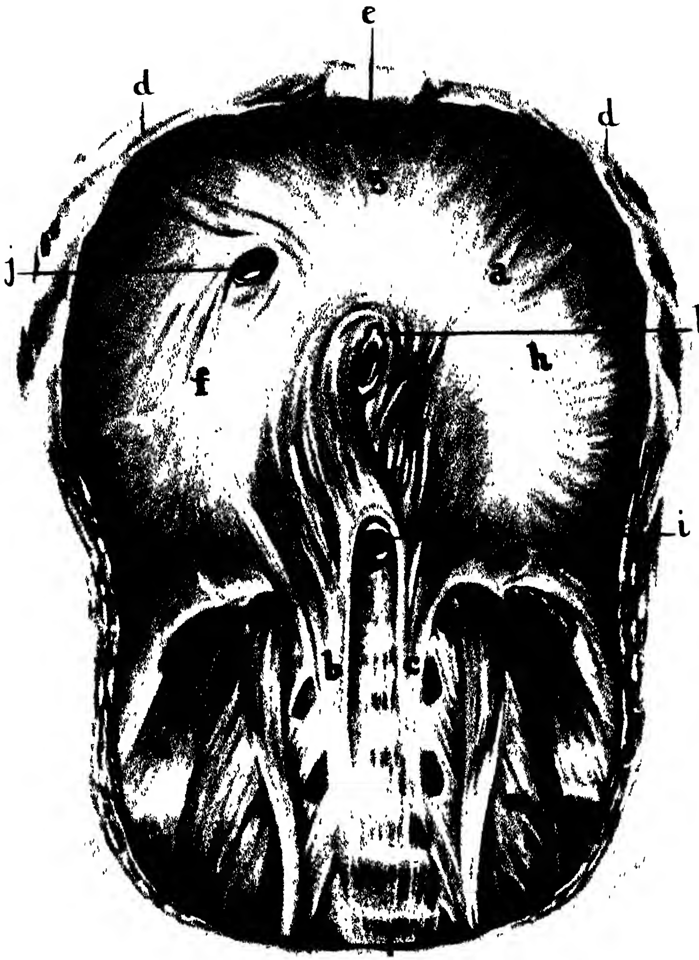
All the above muscles perform different functions. No. 1 and No. 2 pull the head backwards; No. 3 and No. 4 rotate the atlas and the head.

The Muscles of the Thorax

The muscles forming the chest wall are 6 in number, including the diaphragm, the great dividing muscle which is the partition between the thorax and abdomen and which is described separately below. The other muscles are supplied by the intercostal nerves; their functions are to move the ribs. They occupy the intercostal spaces.

Name.	*Origin.*	*Insertion.*	*Remarks.*
1. *External intercostals*	Lower border of each rib	Upper border of rib below	Run downwards and forwards. Raise the ribs
2. *Internal intercostals*	Inner surface of rib	Upper border of rib below	Run downwards and backwards. Raise the ribs
3. *Infracostales*	Inner surface of rib	Inner surface of 1st, 2nd or 3rd rib below	Used in inspiration. Raise the ribs
4. *Transversus thoracis*	Lower third of sternum behind, also lower costal cartilages	2nd to 6th costal cartilages	Depress the cartilages in expiration
5. *Levatores costarum*	Slips begin at each of the transverse processes of the 7th cervical and 1st to 11th dorsal vertebrae	Upper surface of rib immediately below, near its angle	Raise the ribs

The Diaphragm.—This muscle forms a dome with the concavity towards the abdomen. Its upper surface is the floor of the thorax; its lower the roof of the abdomen. It is not unlike a mushroom with two thin stalks. The latter are powerful muscular bands (known as the crura) which arise from the bodies of the lumbar vertebrae and run upwards on the front of the spine towards the middle of the dome into which they are inserted at a tendinous area called the central (or cordiform) tendon. At its margins the diaphragm is attached to the ensiform cartilage and to the inner surfaces of the 6th to 12th ribs; behind, its origin is the arcuate ligament. The last consists on each side of the medial (over psoas) and the lateral (over quadratus) arches. All the muscle fibres run towards the central tendon. The nerves supplying it are the phrenic nerves and the lower intercostal nerves.



DIAPHRAGM. INFERIOR ASPECT.

a, Central tendon. *b*, Right crus. *c*, Left crus. *d*, Costal cartilages. *e*, Xiphoid process. *f*, Right leaflet. *g*, Middle leaflet. *h*, Left leaflet. *i*, Opening for the aorta. *j*, Opening for the inferior vena cava. *k*, Opening for the oesophagus. *l*, Vertebra. *m*, Psoas major m. *n*, Quadratus lumborum m.

The contraction and expansion of the diaphragm are of paramount importance in breathing. When the fibres contract, the thoracic space is increased in volume therefore the lungs can expand and inspiration results. In expiration the opposite action occurs. The central tendon always returns to its normal position, being firmly bound up with the pericardial tissues. The diaphragm when lowered presses on the abdominal organs, and is therefore brought into action when expulsion is indicated i.e. of urine, faeces or a foetus.

Three large openings are present in the diaphragm. The aorta passes down at the posterior edge, between the 2 crura; it is accompanied by the thoracic duct and the vena azygos major.

The oesophagus is found in the muscle tissue, lying almost centrally; as it passes down it is accompanied by the vagi nerves. The inferior vena cava has a canal bounded by 4 edges of tendon; this lies farthest forward. The crura allow the passage of the splanchnic nerves of their respective sides.

In immediate relationship to the diaphragm above are the bases of the lungs covered with the pleura, also the tip of the heart lying in the pericardium. Below is the stomach, on the right side of which is the liver, and on the left the spleen. Posteriorly are the kidneys and the suprarenal glands (Plate V).

The Muscles of the Abdomen

In dealing with the abdominal muscles, it is convenient to group them into 2 groups: 1. Those which flex the thorax on the abdomen and thus contract in bending; 2 The subsidiary muscles. The former group is the main mass, lying on the front of the abdomen, and by its 3 layers forming a strong wall which compresses and supports the contents of the abdominal cavity. There is a good deal of fascia on the anterior abdominal wall, divided into sheaths; and as the arrangement of the various layers is most important from a surgical point of view, it is best to study each muscle separately (Fig. 95).

The External Oblique Muscle.—Arising from the 5th to the 12th ribs by 8 muscular slips, the external oblique spreads out by fibres running medially, downwards and forwards to the front half of the crest of the ilium, and then forms a broad fibrous aponeurosis attached to the pubis, to the white line which passes down the middle of the abdomen (the linea alba) and to the tip of the sternum. This aponeurosis is very important: above it is continuous with that of the pectoralis major muscle; below it forms a thickened margin (inguinal ligament) stretching from the anterior superior spine of the ilium to the tubercle of the pubis. Close to the pubis, the fibres divide to form an opening, the superficial inguinal ring, through which certain structures

pass normally, and several others in the condition called hernia or rupture. Below the ligament, there are 3 distinct compartments, the 1st (lateral) containing the femoral artery, the 2nd

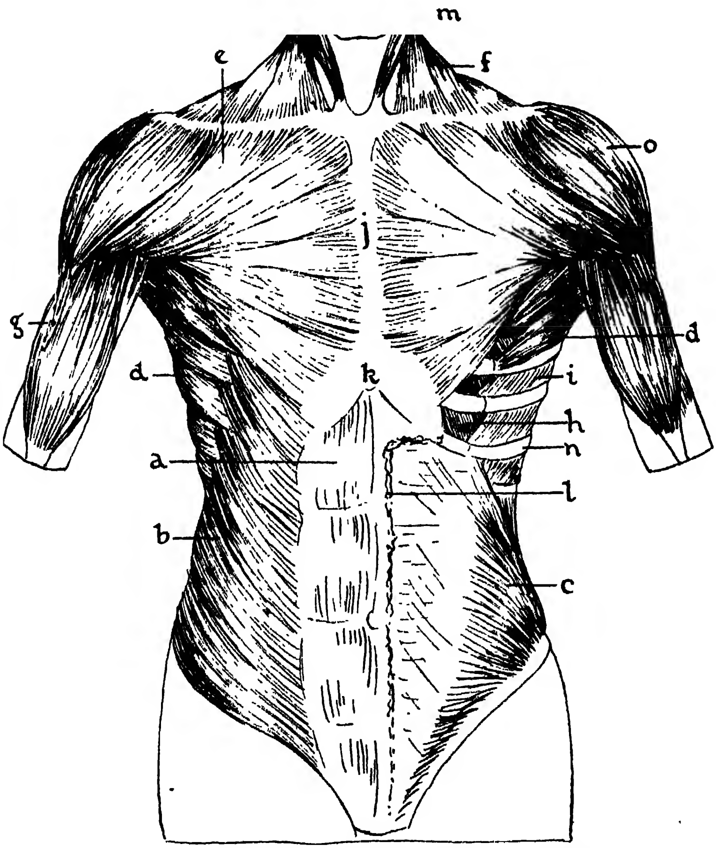


FIG. 95.—MUSCLES OF THE THORAX AND ABDOMEN.

a, Rectus abdominis m. ensheathed. *b*, External oblique m. *c*, Internal oblique m. *d*, Serratus anterior m. *e*, Pectoralis major m. *f*, Trapezius m. *g*, Biceps brachii m. *h*, Internal intercostal m. *i*, External intercostal m. *j*, Sternum. *k*, Xiphoid process. *l*, Rectus abdominis cut away. *m*, Sterno-cleido-mastoid m. *n*, 8th rib. *o*, Deltoid m.

(middle) the femoral vein, and the 3rd (medial) a lymph gland. The last compartment is called the femoral canal. The first 2 compartments are short tunnels in the femoral fascia allowing the

passage of the artery and the vein into the lower extremity. The nerves supplying this muscle are the lower intercostals.

The Internal Oblique Muscle.—The fibres of this muscle, which lies under the external oblique, r un in the opposite direction to it. The origin is the anterior $\frac{2}{3}$ of the crest of the ilium and partly from the inguinal ligament, and the insertion is the cartilages of the 4 lowest ribs, the linea alba and the conjoint tendon, which arches over the spermatic cord at the pubis. The aponeurosis is intimately associated with the rectus abdominis muscle, described below. It is supplied by the lower intercostal nerves and the iliohypogastric nerve.

Rectus Abdominis.—This muscle is the central band passing down the front of the abdomen, with the linea alba as the partition between the right and left masses. It arises from the pubis, and is inserted into the cartilages of the 5th, 6th and 7th ribs. The rectus muscle is enclosed in a sheath formed by the fascia of the external and internal oblique muscles and transversus muscles for about $\frac{3}{4}$ of its length, but the lower $\frac{1}{4}$ has a covering in front only. The lower edge of the deficient posterior fold is called the arcuate linc or linea semicircularis. Three white lines cross the muscle—the tendinous intersections. At the lateral edges the splitting of the aponeurosis is marked by the linea semilunaris. The rectus is supplied by the lower intercosta nerves.

Transversus Abdominis.—The transversus muscle of the abdomen springs from the lateral $\frac{1}{3}$ of the inguinal ligament, the crest of the ilium and the lower 6 costal cartilages, also by an aponeurosis from the lumbar vertebrae. It blends with the linea alba by its anterior aponeurosis and with the internal oblique (conjoint tendon) at the pubic region. It is in relationship with the rectus as described above. Its nerves are those of the internal oblique muscle. The fibres run almost horizontally.

Quadratus Lumborum.—The origin is in the lumbar region, from the iliolumbar ligament and the crest of the ilium, just behind its summit. The fibres pass almost vertically to form a square muscle inserted into the last rib and the transverse processes of the 1st to 4th lumbar vertebrae. It is supplied by the lumbar plexus of nerves.

The above 5 muscles form the main mass of the abdomen. The pyramidalis is in front of the rectus, arising in the anterior pubic ligament, and passing upwards to be inserted into the linea alba midway between the symphysis pubis and umbilicus. It keeps the linea alba tense. The only other muscle is the cremaster, present in the male, and forming over the spermatic cord a series of loops from the inner part of the inguinal ligament. It is intimately associated with the internal oblique. It is supplied by the genitofemoral nerve, its action being to raise the testis.

The Muscles of the Ischiorectal Region

Four muscles are included in this group, chiefly concerned with the evacuation of the rectum and the support of the pelvic floor. The levator ani is the basis of the muscular foundation of this area, its fibres originating in the pubic bone posteriorly, the pelvic fascia and the ischium, and terminating in the centre of the perineum (the part lying in front of the anus and behind the external genital organs), the walls of the rectum, the tip of the coccyx and the thick fibres behind the anus.

The coccygeus muscle acts as a support to the coccyx, running from the ischium and the sacrospinous ligament into the edges of the coccyx and the lowest part of the sacrum.

The external sphincter ani closes the anus; it runs from the tip of the coccyx to the centre of the perineum.

The internal sphincter ani is a mass of circular fibres passing round the rectum just above the anus; these fibres are actually composed of smooth muscle derived from the lower intestine.

The nerves of these muscles are branches of the sacral and pudendal.

The Perineal Muscles

In the Male (5)

Name.	*Origin.*	*Insertion.*	*Action, etc.*
Transversus perinei (Superficial)	Tuberosity of ischium	Central tendon of perineum	Keeps central tendon tense. Nerve: pudendal
Transversus perinei (Deep)	Ramus of ischium	The two muscles meet in the mid-line	Ditto
Bulbospongiosus (*bulbocavernosus*)	Central tendon	The fibres spread out to form a bulbous mass at the bulb of the penis	Accelerates urine. Erects penis. Nerve: pudendal
Ischiocavernosus (*Erector penis*)	Ischium	Crus penis	Keeps penis erect. Nerve: pudendal
Sphincter urethrae	Pubic arch	Unites with its fellow and surrounds membranous urethra	Constricts and compresses urethra

In the Female (5)

Name.	*Origin.*	*Insertion.*	*Action, etc.*
Transversus perinei (Superficial)	As in male	As in male	As in male
Bulbospongiosus (*bulbocavernosus*)	As in male bulbospongiosus	Surrounds opening of vagina, and is inserted into the clitoris	Lessens opening of vagina
Ischiocavernosus	Ischium	Crus clitoridis	Erects clitoris
Transversus perinei (Deep)	Inferior ramus of ischium	Fuses in middle line with muscle of other side	Fixes centre of perineum
Sphincter urethrae	As in male	As in male	As in male

All the above muscles are supplied by the perineal branch of the pudendal nerve.

Muscles of the Upper Extremity

Thoracic Region (4) (Figs. 95 and 96)

Name.	*Origin.*	*Insertion.*	*Action, etc.*
Pectoralis major	Sternal end of clavicle; front of sternum; cartilages of true ribs	Lateral edge of bicipital groove of humerus	Fibres converge into flat tendon. Adducts arm, draws it across chest; raises thorax in deep respiration. Nerves: lateral and medial pectoral
Pectoralis minor	3rd, 4th and 5th ribs	Coracoid process of scapula	Keeps point of shoulder down. Nerve: medial pectoral
Subclavius	1st rib	Subclavian groove of clavicle	Keeps clavicle in position. Nerve: branch of 5th cervical
Serratus anterior	From 8 upper ribs by 9 tags	Vertebral border of scapula (anterior surface)	Raises the point of the shoulder; assists in respiration; the sling-muscle. Nerve: nerve to serratus anterior

Shoulder and Upper Arm (11) (Figs. 96 and 97).

Deltoid.—This is the muscle which forms the rounded part of the shoulder. It arises from the lateral $\frac{1}{3}$ of the clavicle, the acromion process and the spine of the scapula, and is inserted at the deltoid tubercle on the middle of the shaft of the humerus

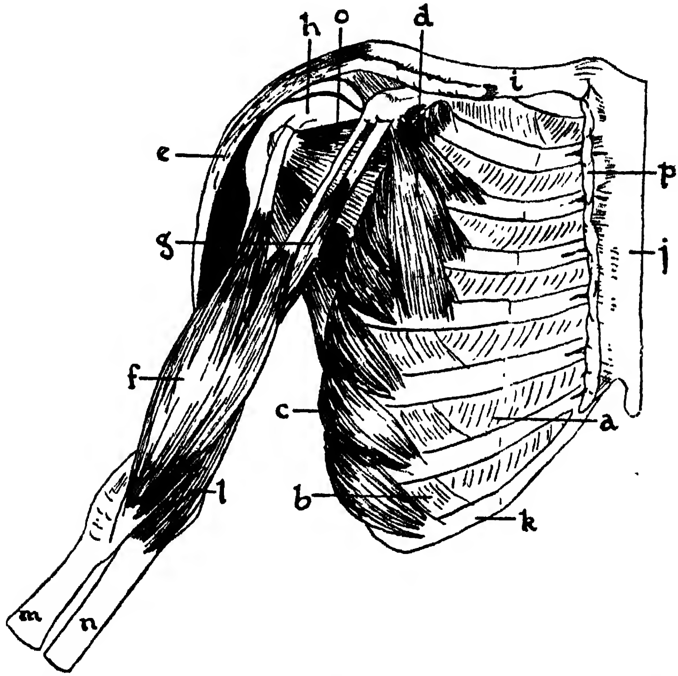


FIG. 96.—MUSCLES OF THE THORAX AND UPPER ARM. ANTERIOR ASPECT.

a, Internal intercostal m. *b*, External intercostal m. *c*, Serratus anterior m. *d*, Pectoralis minor m. *e*, Deltoid m. (cut). *f*, Biceps brachii m. *g*, Coracobrachialis m. *h*, Capsule of shoulder joint. *i*, Clavicle. *j*, Sternum. *k*, 8th rib. *l*, Brachialis (anticus) m. *m*, Radius. *n*, Ulna. *o*, Subscapularis m.

laterally. Its action is to raise the arm into the horizontal position. Nerve supply, axillary (circumflex).

Supraspinatus.—Arises in the supraspinous fossa and goes to the greater tuberosity of the humerus. It also raises the arm. The nerve is the suprascapular.

Infraspinatus.—This arises in the infraspinous fossa, and also

goes to the greater tuberosity. Its action is the lateral rotation of the humerus. It is supplied by the suprascapular nerve.

Biceps.—The greater portion of the fleshy mass on the front of the upper arm is constituted by the biceps muscle, which arises

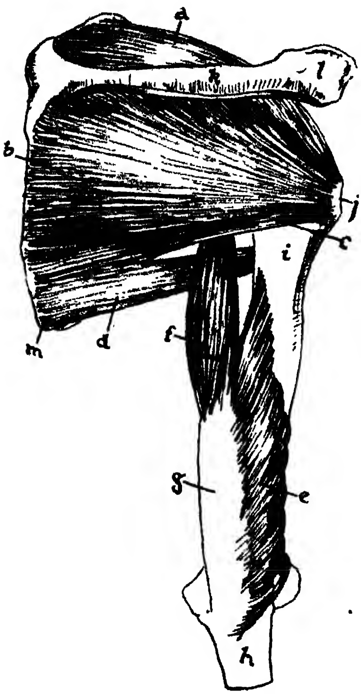


FIG. 97.—MUSCLES OF THE RIGHT SCAPULA AND UPPER ARM. POSTERIOR ASPECT.

a, Supraspinatus m. *b*, Infraspinatus m. *c*, Teres minor m, *d*, Teres major m. *e*, Triceps brachii m. *f*, Long head of triceps m. *g*, Fascia. *h*, Ulna. *i*, Humerus. *j*, Greater tubercle. *k*, Spine of scapula. *l*, Acromion process. *m*, Inferior angle of scapula.

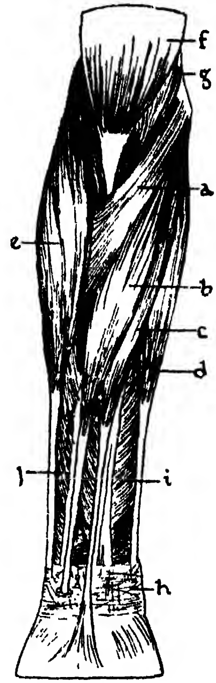


FIG. 98.—MUSCLES OF THE RIGHT FOREARM. ANTERIOR ASPECT. SUPERFICIAL GROUP.

a, Pronator teres. *b*, Flexor carpi radialis. *c*, Palmaris longus. *d* Flexor carpi ulnaris. *e*, Brachioradialis. *f*, Biceps brachii. *g*, Brachialis (anticus). *h*, Flexor retinaculum. *i*, Flexor digitorum sublimis. *j*, Flexor pollicis longus.

from 2 heads (a long head and a short head) from the upper border of the glenoid cavity and from the tip of the coracoid process respectively. The long tendon lies in the bicipital groove of the humerus. The muscle is inserted into the back part of the

tuberosity of the radius and into the fascia on the front of the forearm. It has a double action, flexing the elbow and supinating the forearm, being supplied by the musculocutaneous nerve.

Triceps.—This muscle lies on the back of the upper arm, having, as its name implies, 3 heads of origin: (1) the middle, or long, head from the tuberosity below the glenoid fossa; (2) the lateral head from the shaft of the humerus, above the radial groove; (3) the medial head from the shaft of the humerus, below the radial groove. The muscle ends in the olecranon process. It is supplied by the radial nerve, and its action is to straighten the elbow joint i.e. to extend the forearm on the upper arm.

Other Muscles of Shoulder and Upper Arm

Name.	*Origin.*	*Insertion.*	*Action, etc.*
Subscapularis	Subscapular fossa	Lesser tuberosity of humerus	Rotates humerus medially. Nerves: subscapular
Teres major	Back of inferior angle of scapula	Medial ridge of bicipital groove	Assists latissimus dorsi. Supplied by lower subscapular nerve
Teres minor	Upper ⅔ of dorsal axillary border of scapula	Lowest facet of greater tuberosity of humerus and bone below	Supplied by circumflex nerve, rotates humerus laterally
Coraco-brachialis	Coracoid process of scapula	Middle of shaft of humerus	Pulls humerus upwards, forwards and inwards. Is pierced by musculocutaneous nerve which supplies it
Brachialis (Anticus)	Front of lower shaft of humerus	Coronoid process of ulna	Flexion of elbow. Nerves: musculocutaneous and radial
Epitrochleo-anconeus	Above olecranon fossa	Back of elbow	Keeps ligaments tense

Forearm (Figs. 98, 99 and 100).—The muscles of the forearm can be divided into those lying anteriorly (8 muscles) and those lying posteriorly (12 muscles). The flexors and pronators are in the former group, and the extensors and supinators in the latter group.

Superficial Flexors and Pronators (5)

Name.	*Origin.*	*Insertion.*	*Nerve Supply.*
Pronator teres (pronator of hand)	Medial epicondyle of humerus; and neighbouring fascia. Coronoid process of ulna	Lateral aspect radial shaft	Median
Flexor carpi radialis (flexor of wrist)	Common tendon from medial epicondyle of humerus	Base of index metacarpal	Median
Palmaris longus (keeps palmar fascia tense)	Ditto	Palmar fascia	Median
Flexor carpi ulnaris (flexor of wrist)	Common tendon; medial margin of olecranon	Pisiform bone; 5th metacarpal; hamate	Ulnar
Flexor digitorum sublimis (flexor of fingers)	Common tendon; intermuscular septum; coronoid process of ulna; oblique line of radius	Sides of 2nd phalanges by 4 tendons split by the deep flexor tendons	Median

Deep Flexors and Pronators (3)

Name.	*Origin.*	*Insertion.*	*Nerve Supply.*
Pronator quadratus (pronator of hand)	Lower $\frac{1}{4}$ of ulna	Lower $\frac{1}{4}$ of radius	Anterior interosseous
Flexor digitorum profundus (flexor of hand)	Shaft of ulna and interosseous membrane (upper $\frac{3}{4}$)	Last phalanges. The tendons pass under the flexor retinaculum and then through the split superficial tendons	Anterior interosseous; ulnar
Flexor pollicis longus (flexor of wrist and thumb)	Upper $\frac{1}{2}$ radial shaft	Base of last phalanx of thumb. Passes under flexor retinaculum	Anterior interosseous

In the extensor and supinator group there are 2 supinator muscles and 10 extensors. All are supplied by the radial nerve, or its continuation, the posterior interosseous nerve.

The anconeus is an extensor of the forearm, otherwise the names of the muscles are descriptive of their action.

SUPERFICIAL EXTENSORS AND SUPINATORS (7)

Name.	*Origin.*	*Insertion.*
Brachioradialis (*supinator longus*); supinator of hand	Upper part of lateral epicondyle of humerus	Base of styloid process of radius
Extensor carpi radialis longus	Lower ⅓, lateral epicondyle of humerus	Base of second metacarpal
Extensor carpi radialis brevis	Lateral epicondyle of humerus. Intermuscular septum	Base of third metacarpal
Extensor digitorum	Ditto	By 4 tendons into 2nd and 3rd phalanges
Extensor digiti minimi	Ditto	2nd and 3rd phalanges of little finger
Extensor carpi ulnaris	Deep fascia of forearm; common tendon; posterior border ulna (middle ⅓)	Base of 5th metacarpal
Anconeus	Lateral epicondyle posteriorly	Olecranon; posterior upper shaft ulna

DEEP EXTENSORS AND SUPINATORS (5)

Name.	*Origin.*	*Insertion.*
Supinator (*brevis*)	Lateral epicondyle humerus. Annular ligament of radius. Oblique line on ulna	Neck of radius; occupies ⅓ of shaft
Abductor pollicis longus	Radius and ulna posteriorly. Interosseous membrane	Base of thumb metacarpal
Extensor pollicis brevis	Posterior shaft of radius; interosseous membrane	Base of 1st phalanx of thumb
Extensor pollicis longus	Posterior shaft of ulna; interosseous membrane	Base of terminal phalanx of thumb
Extensor indicis	Posterior shaft of ulna; interosseous membrane	2nd and 3rd phalanges of index finger

Hand (Fig. 101).—The muscles of the hand can be grouped into those of the thenar eminence (which is the fleshy mass at the base of the thumb), 5 in number; those of the hypo-

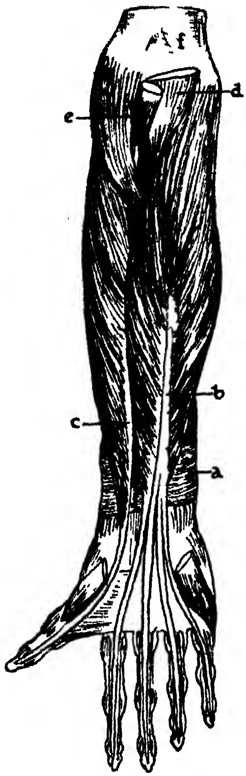


Fig. 99.—Muscles of the Right Forearm. Anterior Aspect. Deep Group.

a, Pronator quadratus m. *b*, Flexor digitorum profundus m. *c*, Flexor pollicis longus m. *d*, Cut brachialis m. *e*, Cut tendon of biceps brachii. *f*, Humerus.

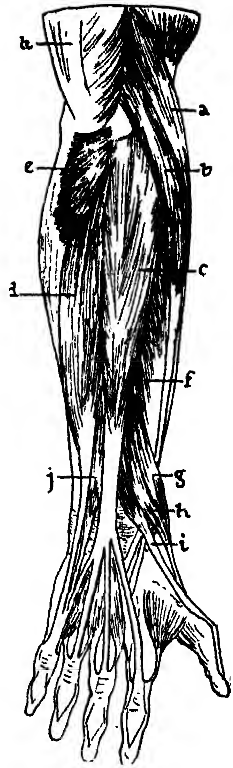


Fig. 100.—Muscles of the Right Forearm. Posterior Aspect.

a, Brachioradialis. *b*, Extensor carpi radialis longus. *c*, Extensor digitorum. *d*, Extensor carpi ulnaris. *e*, Anconeus. *f*, Extensor carpi radialis brevis. *g*, Abductor pollicis longus. *h*, Extensor pollicis brevis. *i*, Extensor pollicis longus. *j*, Extensor digiti minimi. *k*, Triceps brachii.

thenar eminence, in line with the little finger, 4 in number; the lumbricales, 4; and the interossei, 7; a total of 20.

The Thenar Eminence.—The abductor pollicis brevis passes from the greater multiangular and navicular bones of the carpus

and from the flexor retinaculum into the base of the 1st phalanx of the thumb. As its name implies, it draws the thumb away from the middle line. Its nerve is the median.

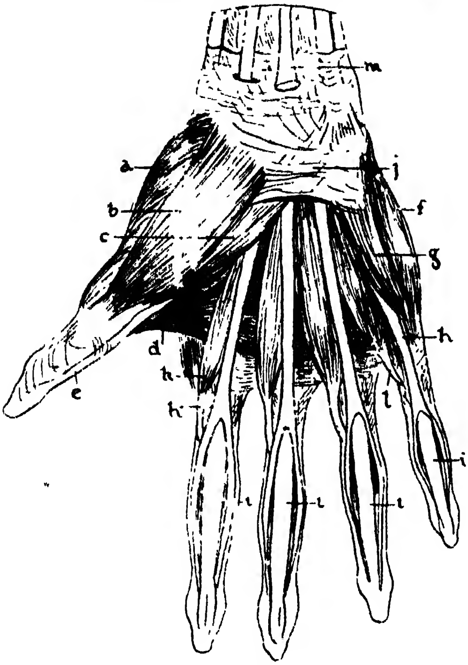


FIG. 101.—MUSCLES OF THE RIGHT HAND. VOLAR ASPECT.

a, Opponens pollicis. *b*, Abductor pollicis brevis. *c*, Flexor pollicis brevis. *d*, Adductor pollicis. *e*, Tendon of flexor pollicis longus. *f*, Abductor digiti minimi. *g*, Flexor digiti minimi. *h*, Tendons of flexor digitorum sublimis. *i*, Tendons of flexor digitorum profundus. *j*, Flexor retinaculum. *k*, 1st lumbricalis. *l*, 4th lumbricalis. *m*, Cut tendon of palmaris longus.

The opponens pollicis has almost a similar origin, but is inserted into the whole length of the lateral aspect of the metacarpal bone of the thumb, which it flexes. Nerve supply as above.

The flexor pollicis brevis arises from the flexor retinaculum and from the 1st metacarpal bone, and is inserted by 2 tendons into the base of the 1st phalanx of the thumb. Its action is to flex the thumb and it is supplied by both median and ulnar nerves.

The adductor pollicis obliquus arises from an area on the carpus round about the capitate bone, and passes to the base of the 1st phalanx of the thumb. It tends to pull the thumb towards the middle line, its nerve being the ulnar.

The adductor pollicis transversus springs from the metacarpal bone of the middle finger and terminates at the base of the 1st phalanx of the thumb; it reinforces the action of the above and is supplied by the same nerve.

The Hypothenar Eminence.—The palmaris brevis passes from the palmar fascia to the skin of the hypothenar eminence, at which it causes a wrinkling action.

The abductor digiti minimi acts as its name indicates; it arises

at the pisiform bone and is fixed at the base of the 1st phalanx of the little finger.

The flexor digiti minimi originates at the hook of the hamate bone and is inserted as above.

The opponens digiti minimi also arises in the hamate bone and is inserted along the whole of the medial side of the 5th metacarpal bone, which it flexes. All the above are supplied by the ulnar nerve.

Lumbricales.—These 4 muscles arise in the deep flexor group, and pass to the dorsum of the phalanges, blending with the extensor tendons and bending the 1st phalanges backwards. They are supplied by both median and ulnar nerves.

Interossei Muscles.—There are 3 on the palmar aspect, and 4 on the dorsal aspect. Those of the palmar group adduct the fingers, being inserted at the bases of the proximal phalanges; they originate in the 2nd, 4th and 5th metacarpals. Those of the dorsal group have origin on either side of the metacarpal bones and go to the middle 3 fingers, the middle finger having 2 muscles. These muscles are concerned with the action of spreading the fingers.

Aponeuroses of the Hand.—*Palmar Fascia.*—Lying deeply in the hand and composed of a thickened portion of the deep fascia is the palmar fascia, which forms sheaths for the 4 fingers.

Flexor Retinaculum of Hand (Transverse Carpal Ligament).—This lies on the palmar surface of the wrist, covering the flexor tendons and the median nerve. The palmaris longus and the flexor carpi radialis are inserted into it in part. It blends with the palmar fascia.

Extensor Retinaculum (Dorsal Carpal Ligament).—This is on the back of the carpus and forms a series of six canals each occupied by extensor tendons.

Muscles of the Lower Extremity

Iliac Region.—The muscular mass which lines the walls of the pelvis and passes forwards out of the pelvis into the thigh bone is sometimes known as the iliopsoas muscle, but it is better to consider it as consisting of 3 muscles viz. psoas major, psoas minor and iliacus (Fig. 102).

Psoas Major.—The psoas major muscle is a long strap-like muscle arising from the bodies, transverse processes and intervertebral discs of the last dorsal and all the lumbar vertebrae, and uniting with the tendon of the iliacus to be inserted at the lesser trochanter of the femur. Its action is to bend the trunk on the thigh or, vice versa, to bend the thigh towards the abdomen. It is supplied by the lumbar nerves. The inguinal ligament passes over it.

Psoas Minor.—The psoas minor may be absent. It acts as a medium for tightening the iliac fascia. Its origin is as above.

Iliacus.—This muscle originates in the hollow of the iliac fossa, also at the sacrum and adjacent structures; its tendon is that of the psoas and it receives a slip from the capsule of the hip. It is supplied by the femoral nerve and has an action similar to that of the psoas major.

The Iliac Fascia.—This fascia is widespread, covering the iliacus and psoas muscles, and therefore lining the back of the abdomen. Below, it is in association with the inguinal ligament, forming a band, the iliopectineal ligament, which passes backwards. The aponeurosis passes downwards into the thigh, behind the great vessels. The front of the abdominal cavity is lined by the transversalis fascia which is prolonged as the anterior part of the femoral sheath.

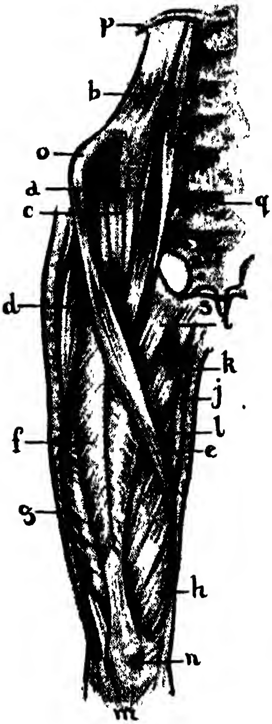


FIG. 102.—MUSCLES OF THE ILIAC REGION AND THE ANTERIOR FEMORAL MUSCLES. RIGHT SIDE.

a, Psoas major. *b*, Quadratus lumborum. *c*, Iliacus. *d*, Tensor fasciae latae. *e*, Sartorius. *f*, Rectus femoris. *g*, Vastus lateralis. *h*, Vastus medialis. *i*, Pectineus. *j*, Gracilis. *k*, Adductor longus. *l*, Adductor magnus. *m*, Tibia. *n*, Patella. *o*, Crest of ilium. *p*, 12th rib. *q*, 5th lumbar vertebra. *r*, Sacrum. *s*, Symphisis pubis.

Muscles of the Hip.—The pelvis is connected with the femur by several muscles which converge to a point at the great trochanter. The prominence of the buttock is caused by the 3 glutei muscles, especially the gluteus maximus, which forms a thick fleshy pad covering the deeper layer, and is a natural cushion when the body is in the sitting posture. The muscles are tabulated overleaf, but on account of its importance, the gluteus maximus is described separately and more fully (Figs. 102 and 103).

Gluteus Maximus.—This has a wide origin forming an area including the ilium and part of its crest, the sacrum and coccyx, the sacrotuberous ligament, the fascia of the erector spinae mass and the fascia of the gluteus medius below. The fibres pass obliquely downwards and laterally (forming the familiar bulge of the buttock) to be inserted into the fascia lata of the thigh (see below) and the line extending from the greater trochanter to the linea aspera. The

nerve supply is the inferior gluteal. This strong muscle not only keeps the body in the erect position, but extends the thigh, rotates it outwards and abducts it (Fig. 103).

Other Muscles of the Hip (Fig. 105)

Name.	*Origin.*	*Insertion.*	*Nerve and Action.*
Gluteus medius	Ilium and neighbouring fascia	Greater trochanter	Superior gluteal. Assists gluteus maximus
Gluteus minimus	Ditto	Ditto	Ditto, but it rotates thigh inwards
Piriformis (passes through greater sciatic foramen)	3 heads: (*a*) sacral, (*b*) and (*c*) sacrotuberous	Greater trochanter	Sacral. Rotates thigh externally
Obturator internus (passes through lesser sciatic foramen)	Obturator membrane and obturator foramen	Ditto	Branch of sacral plexus. Ditto
Gemellus superior	Spine of ischium	Ditto (by tendon of obturator internus)	Ditto
Gemellus inferior	Tuberosity of ischium	Ditto	Nerve to quadratus femoris. Ditto
Quadratus femoris	Ditto	Behind greater trochanter	Sacral. Externally rotates and adducts thigh
Obturator externus	Margin of obturator foramen; obturator membrane	Digital fossa of femur	Obturator. External rotator

Muscles of the Thigh.—The thigh muscles can be grouped into masses according to position and action. Thus the muscles on the front of the thigh are extensors of the knee; those on the back are flexors of the knee; and those on the medial side of the thigh are adductors of the thigh (Figs. 102, 104 and 105).

Group 1.—Forming a spindle-shaped mass on the front of the thigh, and made up of fleshy bands passing from the region of the spines of the ilium to the region of the knee is the 1st group of muscles, consisting of the quadriceps femoris and the sartorius muscles. The latter is the "tailors' muscle," since its action

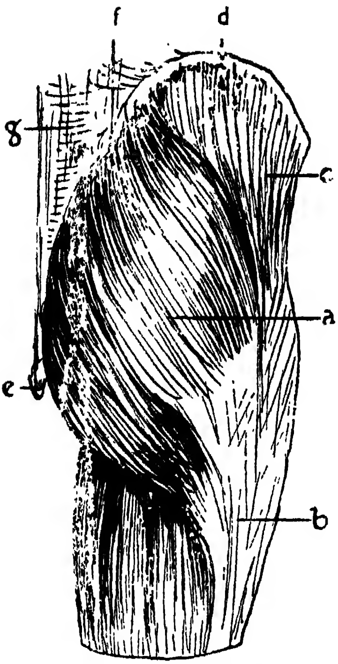


FIG. 103.—THE GLUTEUS MAXIMUS MUSCLE. RIGHT SIDE.

a, Gluteus maximus. *b*, Fascia lata. *c*, Gluteal aponeurosis. *d*, Iliac crest. *e*, Coccyx. *f*, Posterior superior iliac spine. *g* Aponeurosis.

is fully demonstrated when a person is sitting with legs crossed; it arises in the region of the anterior superior spine, and passes down obliquely to the medial side of the thigh, and then goes on farther to become inserted on the medial aspect of the tibia at its upper end.

The quadriceps femoris actually consists of 5 muscles, some of which are difficult to separate from the main mass. These are the rectus femoris, the vastus lateralis, the vastus medialis, the vastus intermedius and the articularis genus. The first 4 have a common termination: in a prominent flat tendon inserted at the patella.

The rectus femoris has 2 origins, from the anterior inferior spine and from the groove above the acetabulum (the reflected tendon). The vastus lateralis springs from the great trochanter and the linea aspera. The vastus medialis arises from the intertrochanteric line and the upper part of the femur, the shaft of the femur and the intermuscular septum. The vastus intermedius has origin from the upper half of the femur and the intermuscular septum. The last 2 muscles are very closely allied, as also is the articularis genus, which passes behind the patella into the capsular ligament. All these muscles extend the leg and are supplied by the femoral nerve.

Group 2.—On the medial aspect of the thigh is another fleshy mass, not quite so prominent as the anterior group. Here we have the adductors of the thigh. The first is the pectineus, which arises in the iliopectineal line and which is inserted into the shaft of the femur below the small trochanter. It adducts the thigh and rotates it outwards. It is supplied by the femoral nerve. The other muscles of the group are all supplied by the obturator nerve, and draw the leg towards the middle line. The adductor longus arises at the pubis and passes to the linea aspera. The adductor

brevis has a similar origin and is inserted above the adductor longus. The adductor magnus is a huge fan-shaped sheet of muscle, arising at the pubis and ischium and becoming inserted along almost the whole length of the femoral shaft; in addition to adduction it has the power of lateral rotation. It has a branch from the sciatic nerve. The substance of the muscle shows several canals for the passage of vessels, the chief being the termination of the subsartorial canal (Hunter's canal) which conveys the femoral vessels towards the back of the knee. The gracilis gives shape to the medial and upper part of the thigh, hence its name. It arises at the symphysis pubis and runs down to the medial surface of the tibia at its upper end. It flexes the knee and rotates it medially in addition to adducting it.

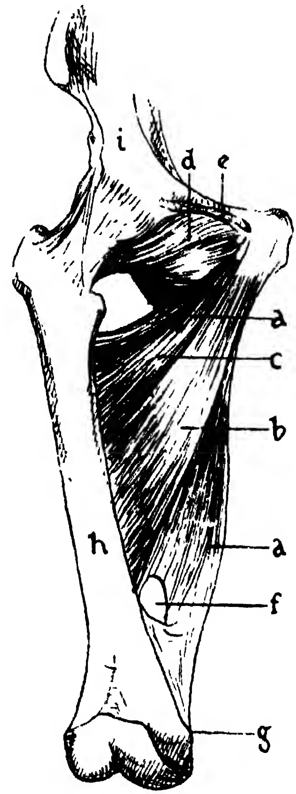


FIG. 104.—MUSCLES OF THE RIGHT THIGH. ADDUCTOR GROUP. ANTERIOR ASPECT.

a, Adductor magnus. *b*, Adductor longus. *c*, Adductor brevis. *d*, Obturator externus. *e*, Pectineus (cut). *f*, Opening for femoral vessels. *g*, Adductor tubercle. *h*, Femur. *i*, Os innominatum.

Group 3.—The hamstring muscles, 3 in number, form a fleshy bulge on the back of the thigh, just as the biceps is responsible for the substance of the front of the upper arm. The biceps of the lower extremity is also similar in that it has 2 heads viz. the long head, arising from the ischium, and the short head, from the linea aspera and the intermuscular septum. The insertion is at the head of the fibula. The semimembranosus also arises from the ischium and passes to the medial condyle of the tibia, spreading out at its insertion to blend with ligaments in the vicinity. The semitendinosus has a similar origin, with a tendon common to the biceps; its fibres pass down on the medial side of the thigh to the medial side of the upper part of the tibia. These 3 muscles are supplied by the sciatic nerve and flex the leg on the thigh, also helping in the action of rotation.

Tensor Fasciae Latae.—This is the last muscle remaining to be

described in this region; it has a special function, that of keeping the vast sheet of deep fascia covering the thigh tense and firm. It arises at the iliac crest and the anterior superior spine and ends about the upper $\frac{1}{3}$ of the lateral surface of the thigh.

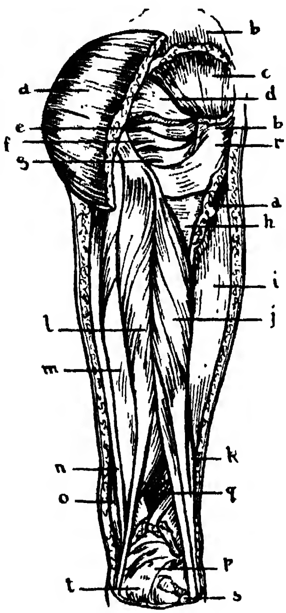


FIG. 105.—MUSCLES OF THE RIGHT THIGH. POSTERIOR ASPECT.

a, Gluteus maximus (cut). *b*, Gluteus medius (cut). *c*, Gluteus minimus. *d*, Piriformis. *e*, Gemellus superior. *f*, Obturator internus. *g*, Gemellus inferior. *h*, Adductor magnus. *i*, Vastus lateralis. *j*, Biceps femoris long head. *k*, Biceps femoris short head. *l*, Semitendinosus. *m*, Semimembranosus. *n*, Gracilis. *o*, Sartorius. *p*, Fascia. *q*, Popliteal space. *r*, Greater trochanter of femur. *s*, Fibula. *t*, Tibia.

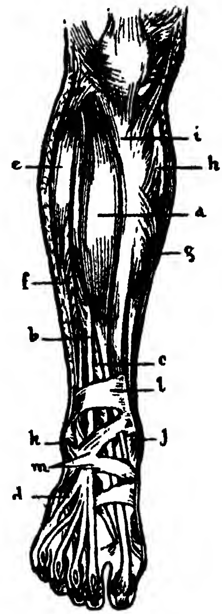


FIG. 106.—MUSCLES OF THE RIGHT LEG. ANTERIOR ASPECT.

a, Tibialis anterior. *b*, Extensor digitorum longus. *c*, Extensor hallucis longus. *d*, Peroneus tertius. *e*, Peroneus longus. *f*, Peroneus brevis. *g*, Soleus. *h*, Gastrocnemius. *i*, Tibia. *j*, Medial malleolus. *k*, Lateral malleolus. *l*, Vertical extensor retinaculum. *m*, Horizontal extensor retinaculum.

The Fascia of the Thigh.—The superficial fascia as elsewhere is in 2 layers, superficial and deep. The latter in the thigh is called Scarpa's fascia and lies over the fascia lata, or deep fascia, where it is called the cribriform fascia, on account of the openings

for the passage of several vessels. The importance of this is apparent when we come to the study of femoral hernia.

The Deep Fascia.—Held taut by the muscle described above, this fascia forms a strong enveloping sheath for the structures of the thigh, extending in front from the inguinal ligament to the knee and behind from the sacrum and coccyx to the back of the knee and the popliteal space. The inguinal ligament is simply a thickened portion of this fascia combined with the fascia of the external oblique muscle of the abdomen. An important opening in the layers of the fascia lata is the saphenous opening at the upper and medial part of the thigh, close to the groin. Through this passes the great saphenous vein.

Muscles of the Leg.—*Front of Tibia.*—Treating the gastrocnemius muscle as belonging to the posterior region, there are 6 muscles on the front of the leg, as shown below (Figs. 106, 107 and 108).

MUSCLES OF FRONT OF TIBIA

Name.	*Origin.*	*Insertion.*	*Nerve and Action.*
Tibialis anterior	Upper part of tibia laterally; interosseous membrane	Base of 1st metatarsal; medial cuneiform	Anterior tibial. Flexes foot on leg; inverts foot
Extensor hallucis longus	Middle portion of fibula and interosseous membrane	Base of terminal phalanx of great toe	As above. Dorsiflexes great toe
Extensor digitorum longus	Lateral condyle of tibia; upper ¾ of fibula	2nd and 3rd phalanges of 4 lesser toes	As above. Tendons spread out over back of foot, one to each toe
Peroneus tertius	Lower ⅓ of fibula	Base of 5th metatarsal	As above. Dorsiflexes tarsus; everts foot
Peroneus longus	Upper ⅔ of fibula	Crosses sole of foot to base of 1st metatarsal, and medial cuneiform bone	Musculocutaneous. Extends ankle joint. Everts foot. Tendon passes behind lateral malleolus
Peroneus brevis	Middle of lateral peroneal area of fibula	Accompanies tendon of above behind lateral malleolus and goes to base of 5th metatarsal	As above. Extends the foot

Back of Tibia.—Seven muscles are included in the group which takes in the muscles of the back of the leg, the chief fleshy mass of the calf being formed by the gastrocnemius and soleus muscles.

Name.	*Origin.*	*Insertion.*	*Nerve and Action.*
Gastrocnemius	Two heads, one on each condyle of the femur	Calcaneum behind, by tendo calcaneus	Medial popliteal nerve. Extends foot; raises body on toes (cf. ballet dancing); pushes body forwards in walking
Soleus	Partly from upper surface of tibia and fibula behind	As above	As above; has additional nerve—posterior tibial
Plantaris	Small fleshy portion from posterior ligament of knee joint	Ditto	As above. Very fine long thin tendon, often ruptured in games
Popliteus	Deeply placed at lateral condyle of femur	Upper part of tibia posteriorly	Medial popliteal. Flexes leg
Flexor hallucis longus	Lower half of fibula posteriorly	Base of last phalanx, great toe	Posterior tibial. Flexes great toe
Flexor digitorum longus	Shaft of tibia behind	Tendon passes behind medial malleolus to bases of terminal phalanges of 4 outer toes	As above. One tendon goes to each toe, splitting the tendon of the flexor brevis digitorum. Flexes toes
Tibialis posterior	Upper posterior halves of tibia and fibula	Tendon passes behind medial malleolus as above, into the navicular, cuboid, cuneiform and metatarsal bones	As above. Inverts foot. Extends tarsus

Muscles of the Foot.—The foot proper has 20 muscles, but only 1 of these is on the dorsum of the foot viz. the extensor digitorum brevis, which arises from the calcaneum and neighbouring ligaments and passes by 4 tendons to the 4 inner toes. Its nerve is the anterior tibial and its action is to extend the toes (Figs. 109, 110 and 111).

On the sole of the foot there are 4 layers, 3 of which are tabulated below.

Name.	*Origin.*	*Insertion.*	*Nerve and Action.*
(1) *Abductor hallucis*	Calcaneum; flexor retinaculum	1st phalanx of great toe	Medial plantar. Abducts great toe
Flexor digitorum brevis	Calcaneum; plantar fascia	2nd phalanges of 4 lesser toes (cf. long flexors)	As above. Flexes lesser toes
Abductor digiti minimi	Ditto	1st phalanx, little toe	Lateral plantar. As named
(2) *Flexor digitorum accessorius*	Calcaneum: long plantar ligament	Tendons of flexor digitorum longus	Ditto
Lumbricales (4)	Long flexor tendons	Back of proximal phalanges	Plantars. Flex toes
(3) *Flexor hallucis brevis*	Cuboid and lateral cuneiform	Proximal phalanx great toe by 2 slips	Medial plantar. Flexes the great toe
Adductor hallucis obliquus	3 middle metatarsals	Lateral surface of base of 1st phalanx	Lateral plantar. Adducts great toe
Flexor minimi digiti brevis	5th metatarsal	Base of 1st phalanx	Ditto. Action as named
Adductor hallucis transversus	Metatarso-phalangeal ligaments of 3rd, 4th and 5th toes	Proximal phalanx great toe	Ditto

(4) *Interossei Muscles* (7).—4 of these muscles are dorsal and 3 plantar. Their nerve supply is the lateral plantar nerve. The dorsal group abducts the toes; the plantar group adducts the toes to the centre of the foot. The fleshy slips, originating in the

metatarsal bones, end in tendinous attachments fixed to the bases of the proximal phalanges.

Fascia of the Foot.—In several areas the foot is provided with well-marked fascial bands, similar to those of the hand (Fig. 112).

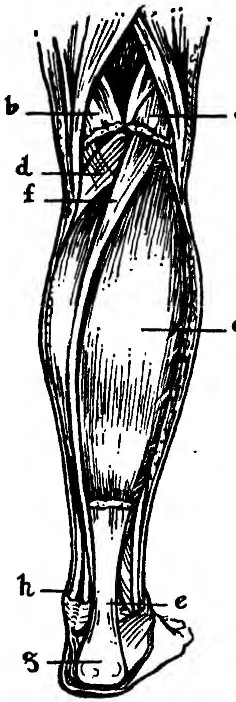


FIG. 107.—MUSCLES OF THE RIGHT LEG. POSTERIOR ASPECT.

a, Lateral head of gastrocnemius. *b*, Medial head of gastrocnemius. *c*, Soleus. *d*, Popliteus. *e*, Tendo calcaneus. *f*, Plantaris. *g*, Calcaneus. *h*, Tendons of muscles of deep group.

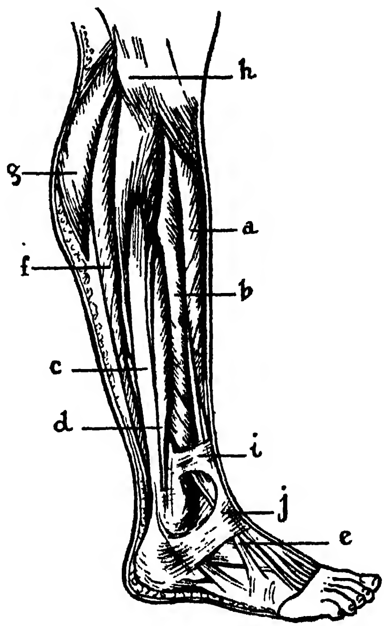


FIG. 108.—MUSCLES OF THE RIGHT LEG. LATERAL ASPECT.

a, Tibialis anterior. *b*, Extensor digitorum longus. *c*, Peroneus longus. *d*, Peroneus brevis. *e*, Peroneus tertius. *f*, Soleus. *g*, Gastrocnemius. *h*, Head of the fibula. *i*, Vertical retinaculum. *j*, Horizontal retinaculum.

There are 3 retinacula. The 1st is called the extensor retinaculum and is divided into the vertical retinaculum (transverse crural ligament) and the horizontal retinaculum (cruciate ligament) which pass over the front of the ankle, forming bands covering synovial sheaths in which the extensor tendons run

(excepting the extensor hallucis longus which passes below). The anterior tibial vessels and the anterior tibial nerve also pass through it. The 2nd is the flexor retinaculum (laciniate ligament) and forms, with 4 grooves on the medial malleolus, canals which transmit the posterior tibial vessels and nerves and

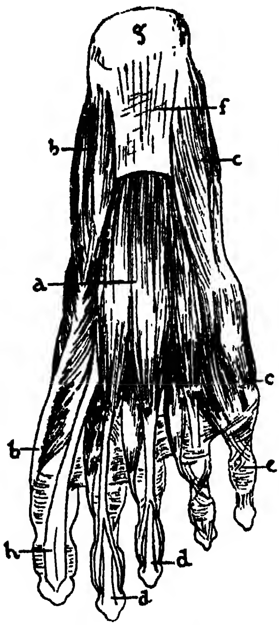


FIG. 109.—THE MUSCLES OF THE RIGHT FOOT. PLANTAR ASPECT. FIRST LAYER.

a, Flexor digitorum brevis. *b*, Abductor hallucis. *c*, Abductor digiti minimi. *d*, Tendons of flexor digitorum longus. *e*, Sheath. *f*, Plantar aponeurosis. *g*, Calcaneus. *h*, Tendon of flexor hallucis longus.

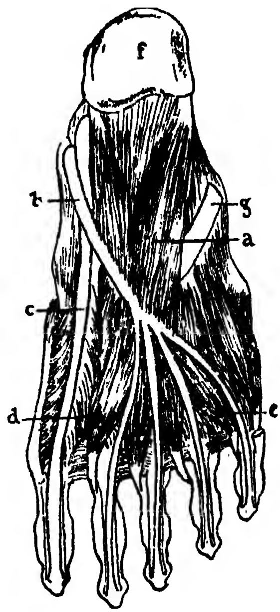


FIG. 110.—THE MUSCLES OF THE RIGHT FOOT. PLANTAR ASPECT. SECOND LAYER.

a, Flexor digitorum accessorius. *b*, Tendon of flexor digitorum longus. *c*, Tendon of flexor hallucis longus. *d*, 1st lumbricalis. *e*, 4th lumbricalis. *f*, Calcaneum. *g*, Tendon of peroneus longus.

flexor tendons. The 3rd (peroneal retinaculum) is on the lateral aspect of the ankle, forming a restricting band for the peroneal tendons.

The plantar fascia is almost as strong as bone, and is the most resistant type of aponeurosis in the body. There are 3 parts, a central and 2 lateral portions, springing from the calcaneum.

Five digitations go to the toes. The dorsal fascia is a continuation of the horizontal retinaculum spreading forward as a thin mem-

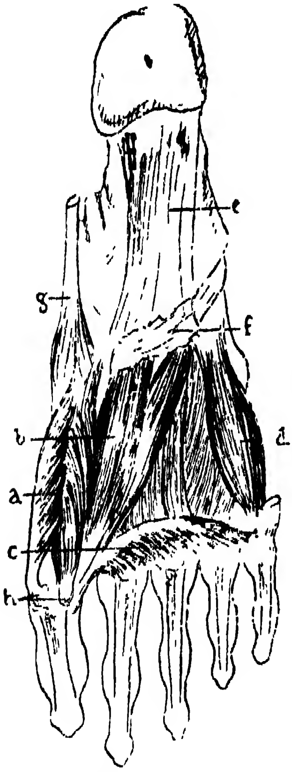


FIG. 111.—THE MUSCLES OF THE RIGHT FOOT. PLANTAR ASPECT. THIRD LAYER.

a, Flexor hallucis brevis. *b*, Adductor hallucis, oblique head. *c*, Adductor hallucis, transverse head. *d*, Flexor digiti minimi brevis. *e*, Long plantar ligament. *f*, Sheath of peroneus longus. *g*, Tendon of tibialis posterior. *h*, Sesamoid bones.

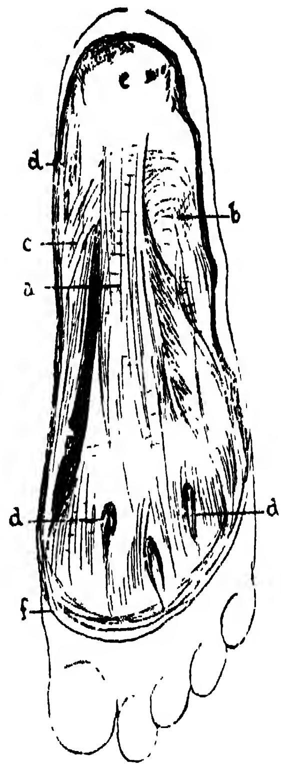


FIG. 112.—THE PLANTAR APONEUROSIS OF THE RIGHT FOOT.

a, Central part. *b*, Lateral part. *c*, Medial part. *d*, Openings for nerves and vessels. *e*, Calcaneum. *f*, Skin (cut).

brane as far as the head of the metatarsal bones, and covering the tendons on the dorsum of the foot.

CHAPTER 9

THE CIRCULATORY SYSTEM—BLOOD

COMPOSITION OF THE BLOOD. COAGULATION OF THE BLOOD. WHAT HAPPENS WHEN BLOOD CLOTS. BLOOD PLASMA AND SERUM. RED BLOOD CORPUSCLES. HAEMOGLOBIN. WHITE BLOOD CORPUSCLES. VARIETIES OF LEUCOCYTES. PHAGOCYTOSIS. BLOOD PLATELETS. SUBSTITUTES FOR BLOOD. BLOOD GROUPS. IMMUNITY.

THE blood is classified as one of the connective tissues, but owing to its close association with the circulatory system it is better to study it along with the blood vessels.

Composition of the Blood

Every tissue of the body receives its regular supply of blood, by which method constant nourishment is provided for the cells. In addition to this the blood acts as the scavenger of the tissues, removing waste products as well as delivering fresh supplies. It is a somewhat sticky fluid resembling a rather fine gum and bright red in colour, on account of the presence of numerous red corpuscles suspended in a yellow liquid known as plasma. The plasma also contains other cell elements, the white blood corpuscles or leucocytes, and a variable number of minute particles called platelets.

Blood is heavier than water and is opaque to light. It has a salty taste, is slightly alkaline and has a heavy odour, easily recognized. About $\frac{1}{13}$ of the body weight consists of blood.

Coagulation of the Blood

So long as blood is circulating in a vessel it is a fluid, but as soon as it is shed (as from a wound) it clots or coagulates, forming a semi-solid material not unlike liver tissue. These properties are obviously of paramount importance to life, ensuring constant nourishment and a defence against bleeding to death in case of injury. Clotting depends upon a substance called fibrin, which

is a nitrogenous material made up of thousands of fine thread-like fibres of protoplasm, apparently radiating from the blood platelets to form a network which supports the red and white blood cells. After a clot has stood for some time it contracts slightly, squeezing out a clear straw-coloured liquid, the serum. Clotting is hastened by the passage of the blood over the rough surfaces of torn vessels and muscles and artificially by shaking it up or whipping it with a thin stick. The process evidently depends upon the presence of an activating agent, thrombin or thrombase. Certain conditions prevent the clotting of shed blood and are frequently taken advantage of in medical practice. For instance blood does not clot unless it wets the surface it passes over; if it is received into an ice-cold receptacle or one coated with wax, clotting may not occur for several hours; the addition of much water prevents clotting; certain chemicals e.g. sodium sulphate, sodium citrate, leech extract and extract of liver may keep the blood in a fluid condition for a long time.

What Happens when Blood Clots.—Numerous theories have been advanced, many of them contradictory, to explain what goes on from the start to the finish of blood clotting. It is generally accepted, however, that in the blood flowing normally through the vessels, there is a parent substance called fibrinogen. As soon as blood is shed, the dormant thrombin becomes active and acts in the presence of certain salts of calcium to liberate fibrin from the fibrinogen. The thrombin is derived from a substance called prothrombin (prothrombase or thrombogen) which acts when stimulated by an enzyme, thrombokinase, produced when blood platelets disintegrate. Diagrammatically expressed the clotting of blood therefore is as given below:

$$\left.\begin{array}{l}\text{Prothrombin}\\ \quad + \\ \text{Calcium}\\ \quad + \\ \text{Thrombokinase}\\ \text{(from blood}\\ \quad\text{platelets)}\end{array}\right\}\text{influence}\left\{\begin{array}{l}\text{Thrombin to act}\\ \text{with Fibrinogen}\end{array}\right\}\rightarrow\text{FIBRIN.}$$

Blood Plasma and Serum.—It is impossible to obtain a pure specimen of plasma outside the body. If non-coagulated blood is kept stable for a few hours, however, or better, if it is treated by a centrifugal machine, the corpuscles sink to the bottom and we can obtain the plasma with a few platelets and various other elements. The fluids in certain cavities of the body are very like plasma, which is alkaline, straw-coloured and contains 10 per cent of solids, consisting of nitrogenous matter (8 per cent), sugars, fats and various salts, chiefly sodium chloride. The

proteins (nitrogenous elements) are chiefly globulins, albumins and fibrinogen.

The Blood Corpuscles

Red Blood Corpuscles.—The total number of red blood corpuscles in the adult is enormous. It is usual to enumerate the cells in 1 cubic millimetre, and the normal count in the male is between 5,000,000 and 6,000,000, while the female blood contains $\frac{1}{2}$ million less. Variations occur in different races and in diseased states of health. There is an increase when the circulation is slow, a decrease when disease destroys the red blood corpuscles.

The individual blood cell, commonly referred to as the erythrocyte, when seen under the microscope (Plate VI), appears to have an outline very like the " men " used in the game of draughts i.e. it is discoid and scooped out on both surfaces. It is an envelope, like all other cells, containing a thick fluid known as haemoglobin. A single blood cell is pale yellow; it is only when blood runs into *rouleaux* formation (Plate VI) that the red colour is brought out strongly. The average diameter is $\frac{1}{3500}$ inch (0·0075 millimetre, generally expressed as 7·5 μ); the thickness is about 2μ. Owing to the elastic properties of the cell envelope, the erythrocyte can change its shape and thus pass through narrow vessels. The nucleus is absent in the red cell except when there is something abnormal in the blood. In the blood of the foetus (unborn child) the erythrocytes are immature and do not have a nucleus. They originate in large nucleated red cells known as megaloblasts; the latter diminish in size until they become of normal calibre. They are then known as normoblasts, or erythroblasts, and can be seen in red bone marrow, which is the great depot for fresh supplies of cells for the blood. These normoblasts lose their nuclei immediately they pass into the circulation, and thus become erythrocytes. Two important factors are essential for the conversion of marrow cells to mature blood cells: 1. haemopoietin, a substance derived from the food and ultimately stored chiefly in the liver, is passed to the marrow in the blood stream and changes the megaloblast into a normoblast; 2. iron, derived also from the food—a substance fundamental in the formation of haemoglobin, which must be supplied to the normoblasts before they can become mature red blood cells.

If water is added to blood slowly, the cells gradually swell until the envelope is ruptured and the haemoglobin escapes. This is called laking or haemolysis. Snake-bite poison acts in the same way.

Haemoglobin.—Erythrocytes normally live for about 6 weeks. They die off and are then taken by the reticulo-endothelial system, a group of widely scattered cells found in the connective tissue, the spleen, the liver and the lymphoid tissues. These have

the power of digesting dead cells and microbes, and especially of forming bile pigment from blood. Ultimately the iron is returned to the circulation in new red cells.

The haemoglobin of the normal red corpuscles in a healthy person is about 14 per cent of the total amount of blood, the normal index being referred to as 100 per cent. Everything depends on the capacity of the blood to carry oxygen and since haemoglobin is the main vehicle for this purpose, the Haemoglobin Index, which is used every day at the bedside, is of vital imporance as a factor illustrating the general state of health. Another important test is the Colour Index Test. This depends upon two factors: 1. the number of red cells per cubic millimetre; and 2. the haemoglobin index. The colour index tells us exactly how

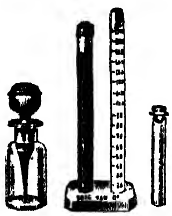


FIG. 113.—HALDANE'S HAEMOGLOBINOMETER.

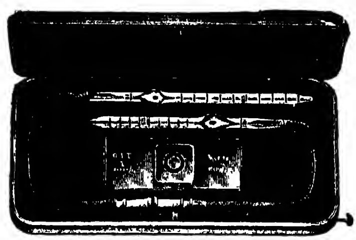
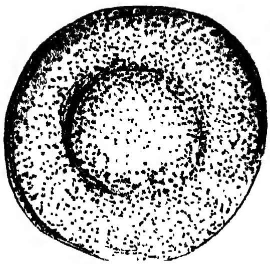


FIG. 114.—HAEMOCYTOMETER.

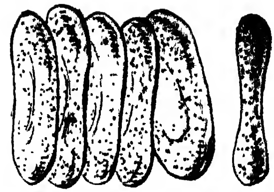
(By courtesy of the Surgical Manufacturing Co. Ltd., London.)

much above or below the normal is the haemoglobin in each cell. Obviously if there are less than 5,000,000 cells per cubic millimetre and excess of haemoglobin, the colour index will be more than 1. If, on the other hand, haemoglobin is weak and the cells normal, the colour index will be less than 1. Many blood diseases are determined by these tests, which are done as a routine every day in hospitals and elsewhere, and the carrying out of which may be part of a nurse's duty. Enumeration of the cells of the blood is done by an apparatus called the haemocytometer; estimation of haemoglobin is made by the haemoglobinometer, many types of which are in use (Figs. 113 and 114).

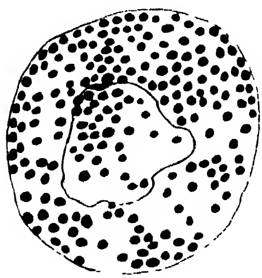
Chemically haemoglobin consists of several substances containing iron in the form of haematin, which takes up oxygen easily, forming oxyhaemoglobin—a vehicle for the transport and distribution of oxygen to the tissues. Other derivatives are haemin, haematoporphyrin and haematoidin, the last identical with the bile pigment and free from iron.



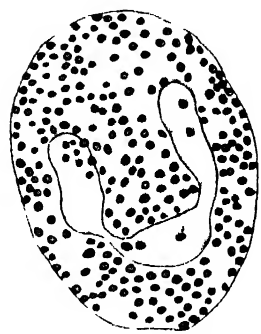
RED CORPUSCLE.



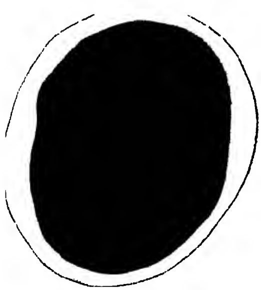
RED CORPUSCLES, FORMING ROULEAUX.



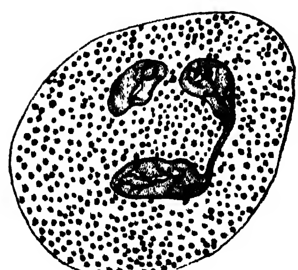
BASIPHILIC LEUCOCYTE.



EOSINOPHIL CORPUSCLE.



LYMPHOCYTE.



POLYMORPHONUCLEAR LEUCOCYTE.

TYPES OF BLOOD CELL.

In addition to uniting with oxygen, haemoglobin takes up other gases e.g. carbon monoxide (coal gas), which turns the blood cherry-red. Blood in arteries is bright red owing to the presence of oxyhaemoglobin; in veins it is purple, due to methaemoglobin, which contains only half the amount of oxygen and is called reduced haemoglobin.

White Blood Corpuscles (Leucocytes).—These cells are larger in size than the red cells but they are less numerous, there being about 7,000 in every cubic millimetre of blood. Individually, they vary considerably in structure and function, but their importance as a whole cannot be overestimated; they are the police force and the cleansing department of the body, waging war incessantly on invading bacteria. Normally a leucocyte is circular or slightly oval in outline, but like the amoeba it can vary its outline; indeed it performs many of the functions observed in that primitive organism.

The chief thing that distinguishes the white cell from the red cell is its nucleus, which may be single or in 2, 3 or 4 sections, lightly joined together by fine threads of protoplasm. Leucocytes have a wonderful power of increasing their numbers (leucocytosis). Ordinarily after every meal they show slight multiplication, but in septic diseases, fevers, pneumonia and other troubles which demand resistance to bacteria, the white cells may reach a total of 50,000 per cubic millimetre. On the other hand, in wasting diseases and in cases of gross debility the number of leucocytes may be substantially decreased; to this condition the term, leucopenia, is applied.

Varieties of Leucocyte.—When a thin film of blood is put on a glass slide and treated with a dye containing red and blue pigments, which stain the granules of the protoplasm, some of the granules take up the red or acid stain, and some the blue or basic stain, whereas the nuclei are invariably blue. This phenomenon is useful as a basis for classification, and thus we divide the white blood cells into 5 distinct groups (Plate VI).

1. *Polymorphonuclear Cells.*—These cells, also called neutrophils, constitute about 70 per cent of the leucocytes; they measure from 6μ–8μ in diameter. Their granules stain a faint purple, hence their name. The nucleus is generally in 3 sections connected by delicate strands of chromatin. In acute septic disease there is a great increase of this type of leucocyte.

2. *Eosinophil Cells.*—Roughly 3 per cent of the total is represented by these cells, which are so called because their rather prominent granules take the red acid stain (eosin) markedly. The nucleus is usually large and very often kidney-shaped. The eosinophil cell measures about 9μ in diameter. An increase occurs in asthma and other allergic states.

3. *Basiphil Cells.*—Known also as mast-cells, these form only

½ per cent of the total in the blood, and measure from 6μ–8μ in diameter. They have a single nucleus, usually bent in the form of the letter S, and the granules take the blue stain which gives them their distinctive appearance.

4. *Lymphocytes.*—The lymphocytes make up about 25 per cent of the leucocytes. They are very slightly larger than the erythrocytes and their nucleus occupies nearly the whole of the cell. These cells are always blue in the blood film as the nucleus takes the basic dye, and the small rim of protoplasm does not contain any granules. The lymphocytes abound in chronic diseases like phthisis, probably increasing the antitoxins.

5. *Transitional Cells.*—This is a larger cell than the lymphocyte, with a nucleus which varies in shape. About 3 per cent exist in the blood. As their name implies, they are " hybrid " cells, probably something half-way between the polymorph and the larger lymphocyte.

The origin of the polymorphonuclear cells is the red marrow, where the parent cells are known as myelocytes, the commonest cells of the marrow. The eosinophils and basiphils also begin in the marrow, the myelocyte showing preponderance of acid-stain granules or basic-stain granules as the case may be. The lymphocytes originate in any of the lymphoid tissues; they reach the blood through the lymph channels, which are discussed in full later (p. 176). The transitional cells (now commonly referred to as monocytes or macrocytes) are of doubtful origin, but the consensus of opinion is that they are products of the reticulo-endothelial system. Some actually declare that the monocyte is a modified lymphocyte.

Phagocytosis.—The method employed by the leucocytes to destroy bacteria and other unwanted material is called phagocytosis. A phagocyte is a leucocyte which is in active process of engulfing and destroying a microbe or microbes. Apparently a system of digestion goes on, often involving the sacrifice of the leucocyte, which then becomes a pus cell; millions of these, together with debris, form the matter, or pus, which comes from any festering area.

Blood Platelets.—More and more attention is being paid to these important cells, which are undoubtedly instrumental in the clotting of blood; they are indeed often referred to as thrombocytes. About 250,000 platelets are present in every cubic millimetre of blood, but they are so small (less than one-half of a red cell) that they are not easily made out. The blood platelet is a cell without a nucleus, but the protoplasm is full of small granules. As mentioned above the platelet breaks up when there is any bleeding and provides the thrombokinase essential to clotting. At one time it was believed that blood platelets were secondary products of disintegrated cells or other

blood substances, but now it is beyond doubt that they have an independent origin, which, although it is not yet clearly determined, is considered to be in the haemopoietic tissues, probably the giant cells. Recently some evidence has been given of the possibility of a blood platelet defence action against bacteria in the blood.

Substitutes for Blood

Two world wars in 30 years have emphasized the importance of replacing lost blood by substituting the blood of a normal healthy person or by using various suitable fluids, and every nurse should understand the process, as she is bound to play her part in giving blood transfusion many times in her professional career.

It is very difficult to make up a " false " blood by compounding exact proportions of the known constituents, but certain salts of sodium, potassium and calcium mixed with gum arabic and a trace of glucose make a very useful " blood " in an emergency. There are many more blood substitutes which have been extensively tried in transfusion but these are better left for consideration later, when the whole subject is discussed in full. (Section VI, Chapter 3, Section IX, Chapter 2.)

Blood Groups

It has always been known that there is a danger in introducing whole blood from one human being into the circulatory system of another. The process of dissolution, or laking, may occur rapidly, with fatal effect. Certain types of blood are compatible however, and years of research have shown that 4 groups of human beings can be determined, according to the compatibility of the bloods concerned. The accepted system now indicates the blood groups as O, A, B and AB. In groups A and B there is incompatibility between the two, because when the blood of A is put into B, or vice versa, clumping of the erythrocytes occurs, a reaction termed agglutination. The cause of this is the presence in the red blood cells of an agent, agglutinogen, and in the plasma of another agent, agglutinin. Group A persons have agglutinogen A and agglutinin β, whereas those in group B have agglutinogen B and agglutinin α. In group AB, there are agglutinogens A and B only, agglutinins being absent. In group O, α and β agglutinins are present, but there are not any agglutinogens. O group indicates the universal donors, because there is no danger of agglutination. Group AB contains the universal recipients, but the latter cannot give blood to those outside their own group.

In addition to the above, there is now known to be present in 85 per cent of human beings an agglutinogen known as the Rh factor. This agglutinogen has no relation to the blood groups discussed above; it is found as a normal constituent of the blood of the Rhesus monkey, hence the use of the term, Rh. The importance of this factor lies in the fact that if a person belonging to the 15 per cent of "negative Rh" individuals happens to require a blood transfusion, and if that blood is from one of the 85 per cent, he or she may not show any immediate signs, but actually an anti-Rh factor has been developed, so that any subsequent transfusion with Rh-positive blood results in laking, and death may occur. Furthermore, there is the complication of pregnancy to be considered. A pregnant woman may be Rh-negative and the foetus may be Rh-positive; as a result of this, the expectant mother stores up "agglutinins" as represented by the anti-Rh factors present. Now in the event of the woman requiring a blood transfusion, and if Rh-positive blood is used, as it might well be, laking of blood and serious or even fatal results may be produced. This subject is being actively investigated.

Blood and Immunity

We know that bacteria are destroyed by the blood. But more than this actually happens. We have only to think of the protection against smallpox by vaccination, which is a mild manifestation of the disease, or against scarlet fever, influenza or whooping cough, to realize that a certain immunity is conferred. This form of protection may be obtained naturally or artificially. In artificial immunity, inoculations and vaccines stimulate the blood to produce protective elements against a specific disease; or the antidote may be injected into the large veins, and may so flood the blood with ready-made "immunity." Normally the blood serum is strongly bactericidal. It is said to contain bacteriolysins, probably derived from the leucocytes. These can be destroyed by heating the serum to 55° Centigrade. Another property, already mentioned (p. 147), is haemolysis. On account of the presence of haemolysins in the blood serum of one animal, the corpuscles of another, when added to it, are burst, with outflow of haemoglobin. Bacteriolysins and haemolysins are very near relatives. The more the former are active, the better is the index of good health. It is well also to remember that illness is the battle for immunity and for supremacy of the bacteriolysins. When the struggle is sharp, and the reaction vigorous, the outcome need not be in doubt. Doctors worry over patients who do not respond to the bacterial attacks. More is said about the property of antitoxins and immunity in later chapters of these volumes.

CHAPTER 10

THE CIRCULATORY SYSTEM—ANATOMY OF THE HEART AND VESSELS

THE HEART. CHAMBERS OF THE HEART. LAYERS OF THE HEART. THE MYOCARDIUM. THE PERICARDIUM. THE ENDOCARDIUM. RIGHT AURICLE. RIGHT VENTRICLE. LEFT AURICLE. LEFT VENTRICLE. VALVES OF THE HEART. THE BLOOD VESSELS. STRUCTURE OF ARTERIES. STRUCTURE OF VEINS. STRUCTURE OF CAPILLARIES. THE MAIN ARTERIES. THE AORTA. ILIAC ARTERIES. THE FEMORAL ARTERY. THE POPLITEAL ARTERY. ARTERIES OF THE LEG AND FOOT. ARTERIES OF THE UPPER EXTREMITY. THE ARTERIES OF THE HEAD. THE PULMONARY ARTERY. THE PRINCIPAL VEINS. SINUSES OF THE HEAD. DRAINAGE OF THE TRUNK AND LOWER LIMBS. THE AZYGOS VEINS. THE PORTAL SYSTEM. THE PULMONARY VEINS. THE SUPERFICIAL VEINS.

THE body requires a regular supply of blood for every tissue. For this a system of pipes and of pumping is necessary, provided by the blood vessels and the heart. There are 3 types of blood vessel: 1. those which convey the blood from the heart to the tissues—the arteries; 2. those which convey the blood from the tissues to the heart—the veins; 3. the connecting system, a fine network of threadlike vessels joining the arteries to the veins—the capillaries.

The lymphatic system, which is a method of drainage of the blood, is closely allied to the circulatory system, but it is described separately (see p. 176).

The Heart

The pump of the circulatory system is represented by the heart, a stout, cone-shaped muscular organ containing hollow chambers, which lies about the middle of the thorax and between the two lungs. The apex points to the left and is lower than the base, thus the heart lies obliquely in the chest, the right border forming an angle with the plane of the diaphragm. About one-half of the heart is covered by the sternum, chiefly the right half.

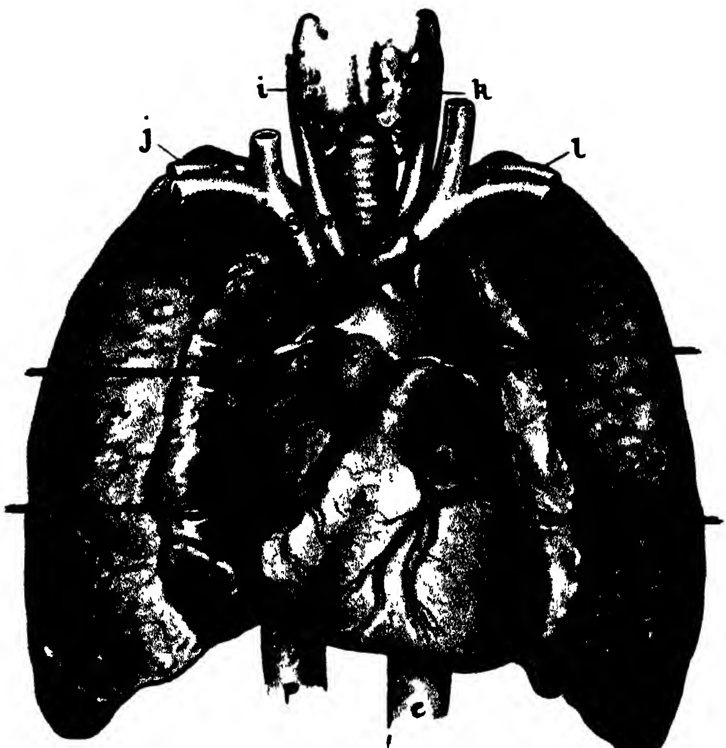
The left border usually lies about $3\frac{1}{2}$ inches from the middle line, and the apex is normally in the fifth intercostal space, just internal to a perpendicular line passing through the left nipple. The heart weighs about half a pound (see Plate VII).

The Divisions of the Heart.—A perpendicular partition divides the heart into a right side and a left side, and each of these cavities is again divided into an upper and lower chamber. The upper chambers were formerly known as auricles, or receivers of blood, but the generally accepted term is atria, each chamber being referred to as the right or left atrium as the case may be; the lower chambers are called ventricles, or distributors of blood. On either side there is a doorway between the auricles and ventricles. The "doors" are the valves, simple yet ingenious; the valves shut off the chamber completely or leave a free passage for the blood as may be necessary. The right atrium therefore communicates with the right ventricle by means of a valve, the tricuspid valve, so-called because it has three cusps; similarly the left atrium is connected with the left ventricle by the mitral valve, so-called because it has two flaps like a bishop's mitre. Blood flows only one way in the heart—from the atria to the ventricles. These valves are like trapdoors on the floors of the atria. The walls of the chamber consist of heart-muscle fibres (see p. 18), and vary in thickness, the ventricles being very muscular. The walls of the left ventricle are about $\frac{1}{2}$ inch thick, and of the right ventricle $\frac{1}{8}$ inch. The walls of the atria are very thin (see Fig. 115.)

The Layers of the Heart.—The great muscular mass of the heart is known as the myocardium, which varies in thickness as described above. It lies between 2 membranes: 1. the pericardium, which envelops the heart like a bag, and 2. the endocardium, which is the inner lining of the heart.

The Myocardium.—The myocardium is composed of bundles of muscle fibres arranged in a network, but in the ventricles definite ridges are formed, some having little pointed peaks which we call the papillary muscles. Certain fine but firm strands of tendinous material pass from the tips of these papillae to the edges of the valves, giving a parachute effect to the structure. Their action is to keep the flaps of the valves in check; they are known as the chordae tendineae.

The Pericardium.—The enveloping membrane consists of 2 layers, which enclose a serous space, small though it may be. The external layer is fixed to the surrounding tissues including the diaphragm; the internal layer is closely applied to the surface of the myocardium. The pericardial fluid varies, but normally it is in sufficient quantity to lubricate the layers and to allow them to glide over each other like the parts of a well oiled engine.



HEART AND LUNGS WITH MAIN BLOOD VESSELS.

a, Right ventricle. *b*, Left ventricle. *c*, Right atrium. *d*, Pulmonary artery. *e*, Aorta. *f*, Superior vena cava. *g*, Right innominate vein. *h*, Left innominate vein. *i*, Right common carotid artery. *j*, Right subclavian artery. *k*, Left common carotid artery. *l*, Left subclavian artery. *m*, Innominate artery. *n*, Right lung. *o*, Left lung. *p*, Inferior vena cava.

The internal layer of pericardium, better known as the visceral pericardium, is elastic, and accommodates itself to the contractions of the heart; on the other hand, the external layer (parietal pericardium) is firm and resistant, thus restraining the heart.

The Endocardium.—The endocardium is the lining membrane of the heart, forming a varnish over the walls of the chambers and smoothing out uneven places, so that the blood flows without hitch. The valves are simply thickened portions of endocardium.

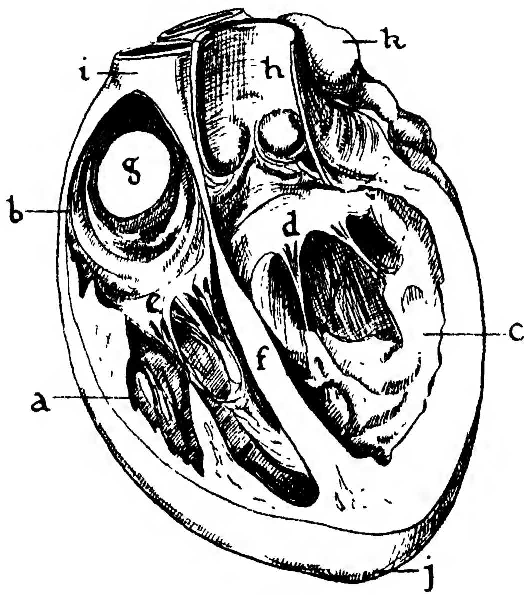


FIG. 115.—LONGITUDINAL SECTION THROUGH THE HEART.

a, Right ventricle. *b*, Right atrium. *c*, Left ventricle. *d*, Mitral valve. *e*, Tricuspid valve. *f*, Ventricular septum. *g*, Inferior vena cava. *h*, Aorta. *i*, Superior vena cava. *j*, Apex of the heart. *k*, Left atrium.

The Chambers of the Heart.—The right atrium (auricle) is a thin-walled chamber situated at the right-hand corner of the heart. An important little hollow is seen on the posterior wall; it is called the fossa ovalis, and marks the former communication between the two atria. If this opening happens to remain unclosed after birth, the child shows clear and well recognized symptoms, commonly met with in nursing. Several large veins open into this chamber, which is the receptor of all the blood from the body e.g. the superior and inferior vena cava and the coronary sinus.

The right ventricle would be in view if the sternum were removed; it occupies almost the whole of the front of the heart. Its roof is formed by the tricuspid valve, while from it there originates the pulmonary artery, guarded by the semilunar valves.

The left atrium (auricle) lies behind the main mass of the heart, in the top left-hand corner. The 4 pulmonary veins open into it.

The left ventricle is the most important of the heart chambers, and takes up the best part of the posterior surface, its apex encroaching on the left margin. Almost side by side are its 2 systems of valves, the mitral, already mentioned, and the semi-

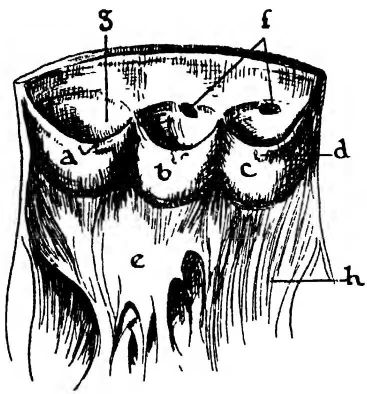


FIG. 116.—SEMILUNAR VALVES.
The aorta has been cut open.
a, Right posterior valve. *b*, Left posterior valve. *c*, Anterior valve. *d*, Nodulus. *e*, Mitral valve. *f*, Openings of the coronary arteries. *g*, Aortic sinus. *h*, Wall of left ventricle.

lunar, guarding the aorta, which is the largest artery of the body, and which is the first trunk of the branching system of blood vessels spread over the body.

The Valves of the Heart.—We have learned that there are 4 sets of valves in the heart, 2 semilunar systems, 1 mitral and 1 tricuspid. The two latter are known as atrioventricular valves, and are fixed to the tendinous rings between the auricles and ventricles; their free edges are controlled by the chordae tendineae, and therefore with the papillary muscles of the myocardium. The semilunar valves are quite different, and much simpler (Fig. 116). Each consists of 3 small pouches attached to the ring of the aorta or pulmonary artery, marking

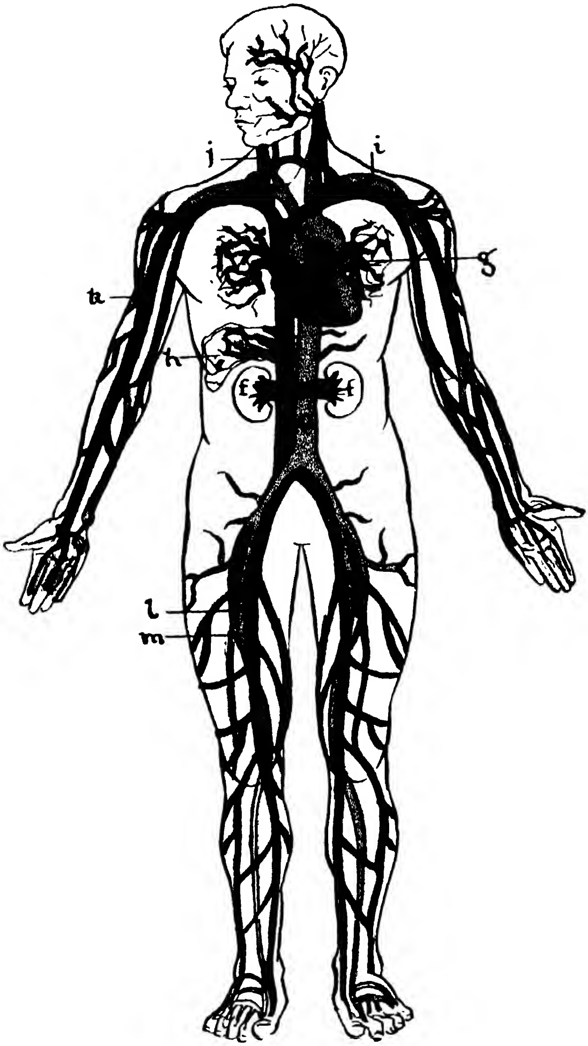


DIAGRAM SHOWING THE CHIEF BLOOD VESSELS OF THE BODY. ANTERIOR ASPECT.

Red represents arterial blood. Blue represents venous blood.

a, Heart. *b*, Pulmonary artery. *c*, Aorta. *d*, Superior vena cava. *e*, Inferior vena cava *f*, Kidneys. *g*, Blood vessels of the left lung. *h*, Blood vessels of the liver. *i*, Subscapular artery. *j*, Common carotid artery. *k*, Brachial artery. *l* Femoral artery. *m*, Femoral vein.

the start of the vessel proper. It is obvious that blood can pass from the ventricle to the blood vessel over these valves, but a back flow of blood in the vessel will fill them and so close them. Later on we shall see that this is exactly what happens in the circulation of the blood.

The Blood Vessels

As a general rule the arteries carry the pure blood to all parts of the body, while the veins take back the impure blood to the heart, where it is transferred to the lungs. The vessel which takes the impure blood from the right ventricle to the lungs is the pulmonary artery, therefore this is the only artery which carries venous blood. Similarly the veins which return the purified blood from the lungs to the heart (the pulmonary veins) are the only veins which carry arterial blood (Plate VIII).

Structure of Arteries.—Every artery has 3 coats as described below.

1. *The External Coat*, or *Tunica Adventitia.*—This coat is areolar tissue with a large percentage of elastic in it, often increased towards the inner layers.

2. *The Middle Coat*, or *Tunica Media.*—The basis is areolar tissue, but muscle elements predominate, although there are also elastic strands. It is the great contracting coat of the three, and by its muscle and elastic keeps up the blood pressure and the tone of the vessel. Like the myocardium, it is the thickest layer, being very marked in the large vessels, which contain a greater quantity of elastic as compared to the smaller arteries, in which the muscle element is the feature.

3. *The Inner Coat*, or *Tunica Intima.*—This is very delicate, being formed of a layer of flattened epithelium on a basis of elastic tissue. Its great characteristic is smoothness (cf. endocardium).

All arteries are supplied with tiny blood vessels, the vasa vasorum, which nourish their walls, and with sympathetic nerves.

Structure of Veins.—Veins have three coats, and in general resemble the arteries, but with certain specific differences. First the outer coat is thicker and has more muscular tissue; secondly the middle coat is much less muscular than that of the artery, and is thinner; thirdly the internal coat is very fine, often absent in the small veins. But the great difference between the arteries and the veins is that the latter possess valves. These are placed so that the free margin looks towards the heart i.e. against any recoil of blood passing to the heart. They occur usually in pairs. The commonest site for these valves is in the legs, where they are most useful in forming stepping-stones for the columns of blood being sucked back to the right atrium. When these valves break

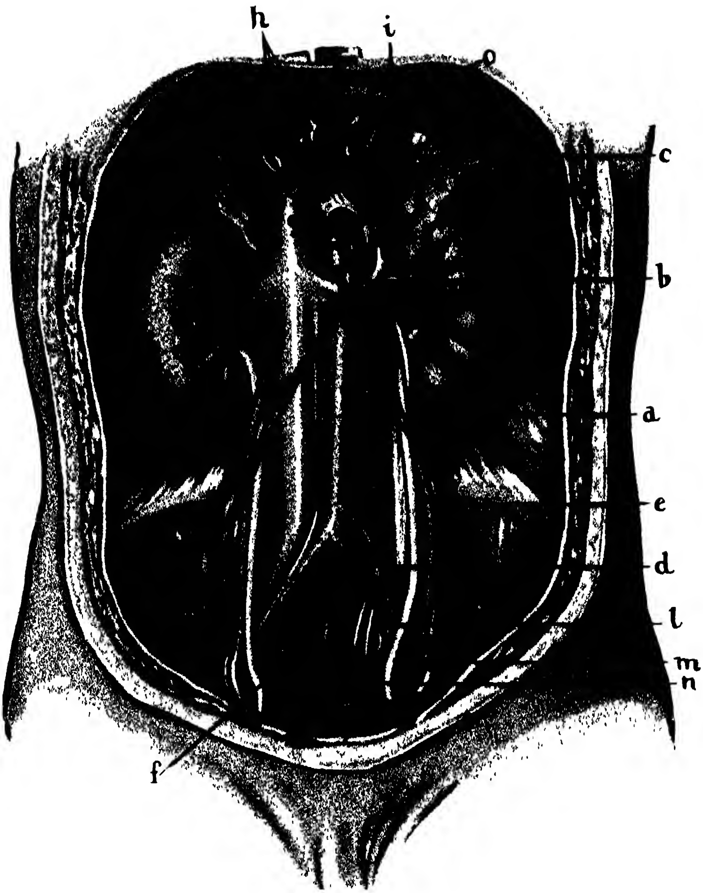
down, the condition of varicose veins results. Certain veins do not have valves: the superior vena cava, the inferior vena cava, the pulmonary veins, the veins of the cranium.

Structure of Capillaries.—The network of fine vessels, many less than a hair's-breadth, which joins the arteries to the veins is of great importance, and is receiving more and more attention as time goes on. A capillary vessel is a terminal artery which has apparently lost its outer and middle coats, and it is an elementary tube consisting of the endothelium of the artery. Capillaries subdivide to form an irregular pattern very like a fishing net. There is a certain contractile power in the capillaries, but it is doubtful whether this is due to remnants of the middle arterial coat or not. The capillaries are the final distributing system of the blood and the delicacy of the walls allows easy interchange of lymph and gases. In the same way as the arteries give place to capillaries, capillaries gradually merge into veins.

The Main Arteries

The Aorta.—This is the name given to the large arterial trunk which leaves the left ventricle at the semilunar valve. Just above its origin, it gives off 2 coronary arteries, which supply the muscle of the heart itself, and which are frequently involved in heart diseases, giving rise to certain signs. Arching over the base of the heart to the left, the aorta rises as high as the manubrium sterni. It gives off 1. the innominate artery, which runs up about 2 inches and then divides into the right common carotid artery and the right subclavian artery; 2. the left common carotid artery; 3. the left subclavian artery. These 3 vessels provide for the circulation of the head and neck. The aorta travels vertically downwards behind the heart, passing through the diaphragm close to the vertebral column, and becomes the abdominal aorta. In the thoracic part of the aorta, various small branches go to the pericardium, the lungs, the oesophagus and the intercostal areas. The abdominal aorta (see Plate IX) gives off the following branches as it passes down on the left side of the spinal column:

1. Phrenic (2), supplying the diaphragm.
2. Coeliac artery, dividing into the gastric, hepatic and splenic arteries, which supply stomach, liver and spleen, and pancreas respectively.
3. The superior mesenteric artery and
4. The inferior mesenteric artery, both supplying the intestines and mesenteries and forming junctions (anastomoses) with other arteries.
5. Renal (2), supplying the kidneys.



ABDOMINAL AORTA AND ITS BRANCHES.

a, Aorta. *b*, Superior mesenteric artery. *c*, Left inferior phrenic artery. *d*, Inferior mesenteric artery. *e*, Left testicular artery. *f*, Middle sacral artery. *g*, Inferior vena cava. *h*, Hepatic veins (cut). *i*, Diaphragm. *j*, Left kidney. *k*, Right kidney. *l*, Common iliac artery. *m*, External iliac artery. *n*, Internal iliac artery. *o*, Oesophagus.

6. Suprarenal, going to the suprarenal glands.
7. (*a*) Testicular, in the male, supplying the testes.
   (*b*) Ovarian, in the female, supplying the ovaries.
8. Lumbar (4), to various muscles in the lumbar region.
9. Median sacral, supplying the coccyx.

The Iliac Arteries.—At the level of the umbilicus (or the 4th lumbar vertebra), the aorta divides into two, forming the right and left common iliac arteries. Thereafter the right side is a duplicate of the left side. The right common iliac again divides into the right external and internal iliac arteries. The internal iliac artery supplies most of the pelvic organs, giving off from its anterior trunk vesical, obturator, uterine, vaginal, pudendal and inferior gluteal branches, supplying the bladder, genital organs, muscles of the pelvis and hip, uterus and perineum; and from its posterior trunk superior gluteal, iliolumbar and lateral sacral branches. The external iliac artery, after giving off small muscular branches, passes below the inguinal ligament to become the femoral artery.

The Femoral Artery.—This artery passes down the medial side of the thigh from the inguinal ligament to an opening in the adductor magnus muscle, through which it passes to the back of the thigh to become the popliteal artery. For the first 2 inches, the artery is very superficial, passing from the fold of the groin into a triangular area known as the femoral triangle. It gives off small branches to the skin, glands and tissues of the region, including the generative organs, and then splits into 2 parts—the deep femoral artery and the superficial femoral artery. The former supplies the lower third of the back of the thigh; the latter passes through a canal called the subsartorial canal and pierces the opening in the adductor magnus, emerging from the muscle at the lower third of the thigh as above described.

The Popliteal Artery.—This is a continuation of the femoral artery behind; it runs down the back of the knee to the lower border of the popliteus muscle, at which level it divides into the anterior and posterior tibial arteries. It bisects a diamond-shaped space called the popliteal space. Its branches supply the structures in the vicinity of the knee joint.

Arteries of the Leg and Foot.—The anterior tibial artery runs from the bend of the knee to the back of the foot, where it becomes the dorsalis pedis artery, on the front of the ankle joint. Its course lies on the front of the interosseous membrane and finally on the lower third of the tibia. It gives branches to the muscles of the leg, and also to the medial and lateral malleolus.

The dorsalis pedis is the continuation of the above, running along the medial side of the foot and giving off branches to the tissues in the region of the tarsus and metatarsus, also to the great

toe. It finally buries itself in the sole of the foot and forms, with the termination of the posterior tibial artery, the plantar arch.

The posterior tibial artery runs along the back of the tibia covered by the thick muscles of the calf. It passes into the foot by a channel behind the medial malleolus and then divides into lateral and medial plantar arteries. It gives off one large branch —the peroneal artery—high up in its course, the two vessels supplying the muscles of the back of the leg and the lateral group, also the tibia and fibula. Lower down the heel and sole of the foot receive branches.

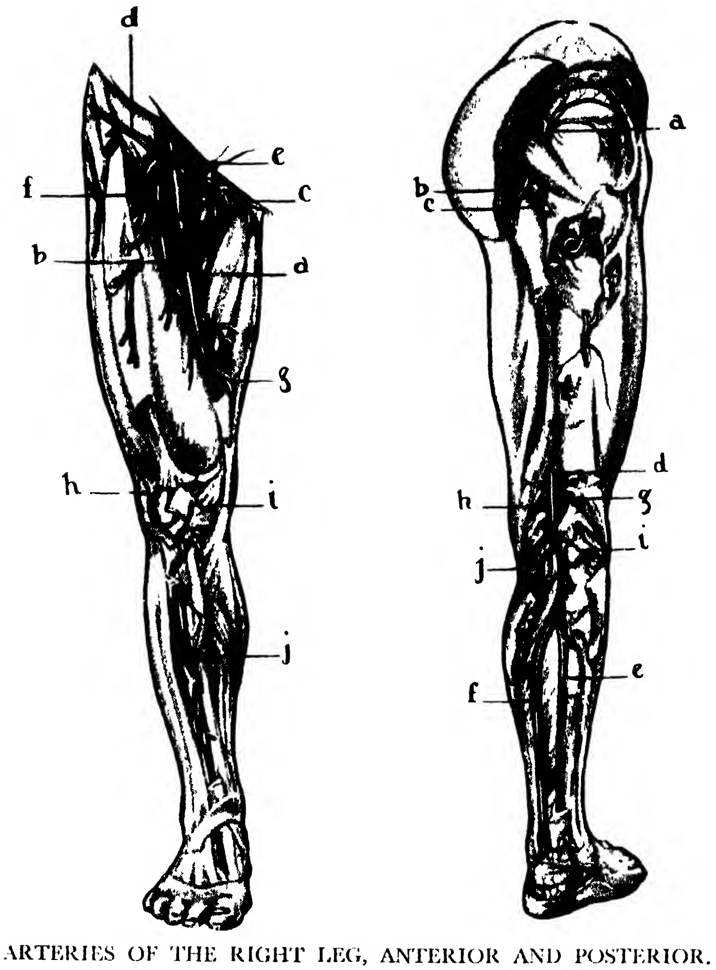
The medial plantar artery runs along the inner side of the foot to the great toe.

The lateral plantar artery crosses the sole of the foot in a curved line, giving off branches to the toes and uniting with the dorsalis pedis to form the plantar arch (Plate X).

The Arteries of the Upper Extremity.—*The Subclavian Artery.*—We have followed the course of the main trunk of the aorta, which supplies the lower part of the body. We now deal with the blood supply of the shoulder and arm. This originates in the subclavian artery, which comes direct from the aorta on the left side, but has a short stump of the innominate artery as its commencement on the right side. It ends as the axillary artery, at the lower border of the first rib. During its course it gives off several very important branches above and below. The vertebral branch goes to the skull, passing through the foramen magnum, where it unites with its fellow of the opposite side to form the basilar artery, especially associated with the nourishment of the brain. The thyrocervical artery is like a tree trunk with its spreading arms, sending out vessels to nourish the tissues of the neck, the scapula, the shoulder, the thyroid gland, the gullet, the windpipe and other structures. The internal mammary artery runs down behind the costal cartilages and supplies the structures of the upper part of the thorax. The costocervical artery nourishes the spinal cord and the muscles of the spine and back of the neck.

The Axillary Artery.—The course is from the lower border of the first rib to the lower edge of the axilla, just where it meets the line of the humerus. The artery is crossed by the pectoralis minor muscle, which divides it into 3 parts. It is surrounded in its middle third by the large mass of nerves known as the brachial plexus. There are 6 branches of note—the superior thoracic, the acromiothoracic, the lateral thoracic, the subscapular, the posterior circumflex humeral and the anterior circumflex humeral, all ensuring a supply of blood to the chest and shoulder muscles, the glands and the walls of the thorax (Plate XI).

The Brachial Artery.—Starting where the axillary artery ends,



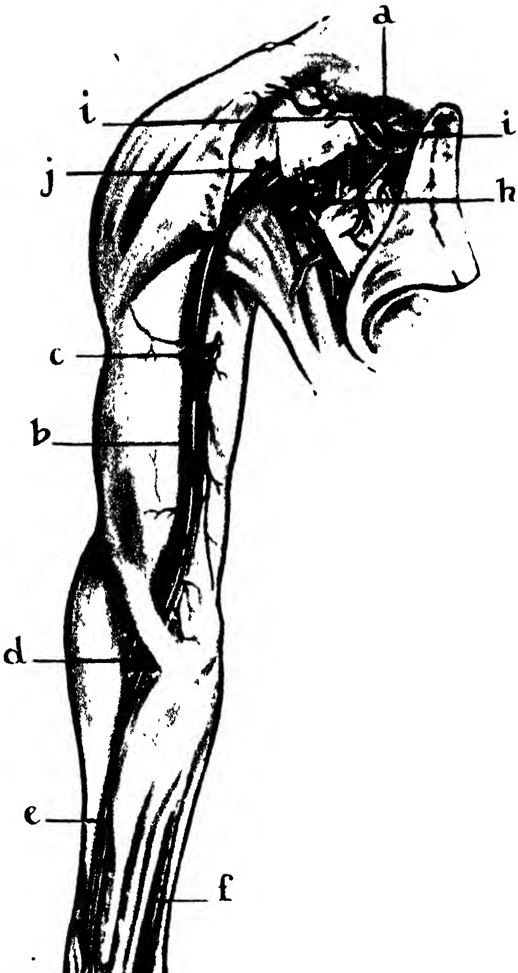
ARTERIES OF THE RIGHT LEG, ANTERIOR AND POSTERIOR.

ANTERIOR ASPECT.

a, Femoral. *b*, Arteria profunda femoris. *c*, Deep external pudendal. *d*, Superficial circumflex iliac. *e*, Superficial external pudendal. *f*, Lateral circumflex femoral. *g*, Highest genicular. *h*, Lateral superior genicular. *i*, Medial superior genicular. *j*, Anterior tibial.

POSTERIOR ASPECT.

a, Superior gluteal. *b*, Inferior gluteal. *c*, Pudendal. *d*, Popliteal. *e*, Peroneal. *f*, Posterior tibial. *g*, Superial lateral genicular. *h*, Superior medial genicular. *i*, Inferior lateral genicular. *j*, Inferior medial genicular.



ARTERIES OF THE RIGHT ARM. ANTERIOR ASPECT.

a, Axillary artery. *b*, Brachial artery. *c*, Arteria profunda brachii. *d*, Radial recurrent artery. *e*, Radial artery. *f*, Ulnar artery. *g*, Superficial volar arch *h*, Subscapular artery *i*, Thoraco-acromial artery. *j*, Posterior humeral circumflex artery.

the brachial artery passes down the medial side of the biceps muscle and becomes superficial at the front of the elbow joint. At a point half an inch below the middle of the bend of the elbow, the artery divides into 2 main trunks, the radial and ulnar arteries. In its course, the artery is crossed by the median nerve. It gives off one large branch, the profunda brachii, which supplies the triceps muscle, and several to the bone, muscles and other tissues of the upper arm.

The Radial Artery.—This runs from the bend of the elbow to the deep palmar arch. As its name implies, it supplies the structures on the radial side of the forearm and hand, including the thumb, the wrist and the metacarpal region. At the styloid process of the radius the artery is just below the skin, and can be seen and felt. It is here that the pulse is observed.

The Ulnar Artery.—This vessel supplies the muscles on the medial half of the forearm, and ends at the wrist in the deep volar arch and superficial volar arch. High up in its course the ulnar artery gives off a large branch, the interosseous artery, which itself divides into 2 branches, supplying the deep and middle tissues of the forearm, the anterior and posterior interosseous branches. In the hand and wrist, branches go to join branches of the radial artery, there being a free anastomosis in this region, anteriorly and posteriorly. The superficial palmar (or volar) arch and the deep palmar (or volar) arch are vascular supplies for different levels of the palm of the hand. The superficial arch is the continuation of the ulnar artery and sweeps round towards the thumb to meet a branch of the radial artery. In its course it sends branches to the fingers. The deep arch is completed by the deep palmar branch of the ulnar artery. From the arc so formed, vessels run to the thumb and fingers. It will be noted that the blood supply to the hand and fingers is very well provided for, reaching these areas by several routes and forming a network of small vessels. This is important in healing of wounds.

The Arteries of the Head.—There remain to be described the great carotid arteries of the body. On the right side the common carotid is a continuation of the short innominate artery; on the left it springs direct from the arch of the aorta, dividing into the external and internal carotid arteries.

The External Carotid Artery.—Eight main branches arise from this artery to supply the neck and side of the face. It begins at the upper border of the thyroid cartilage, and passes up the side of the neck, behind the angle of the lower jaw and in front of the ear, ending in 2 trunks. One trunk goes on as the superficial temporal artery and spreads out over the temple region; the other passes behind the lower jaw as the maxillary artery and gives off about 20 branches, deeply placed in the facial muscles, to the

structures of the area supplied, including the ear, the brain, the jaws, the muscles of the face, the orbit, the palate and the pharynx. Other branches of note are the facial artery, which passes over the lower jaw and supplies the lower part of the face, and the occipital artery, supplying the back of the head (Plate XII).

The Internal Carotid Artery.—This vessel lies deeply in the neck, passing upwards over the transverse processes of the 1st, 2nd and 3rd cervical vertebrae in the region of the tonsil, and entering the carotid canal of the temporal bone. It runs a very tortuous course, forming many S-shaped bends in the interior of the skull. Ultimately it ends by dividing into its cerebral branches. No branches are given off from this artery until it reaches the skull. The following are the most important: 1. the ophthalmic, which passes to the orbit through the optic foramen, and gives off about a dozen branches to both the orbit and the eyeball; 2. the anterior cerebral, which anastomoses freely with the posterior cerebral arteries, after supplying the surface of the brain; 3. the middle cerebral (the main branch), which runs outwards over the middle area of the brain; and 4. the posterior communicating, joining the posterior cerebral branch of the basilar artery.

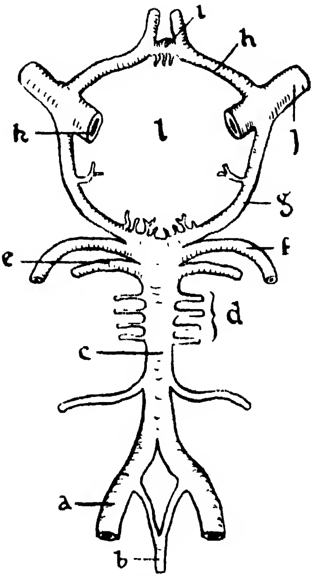
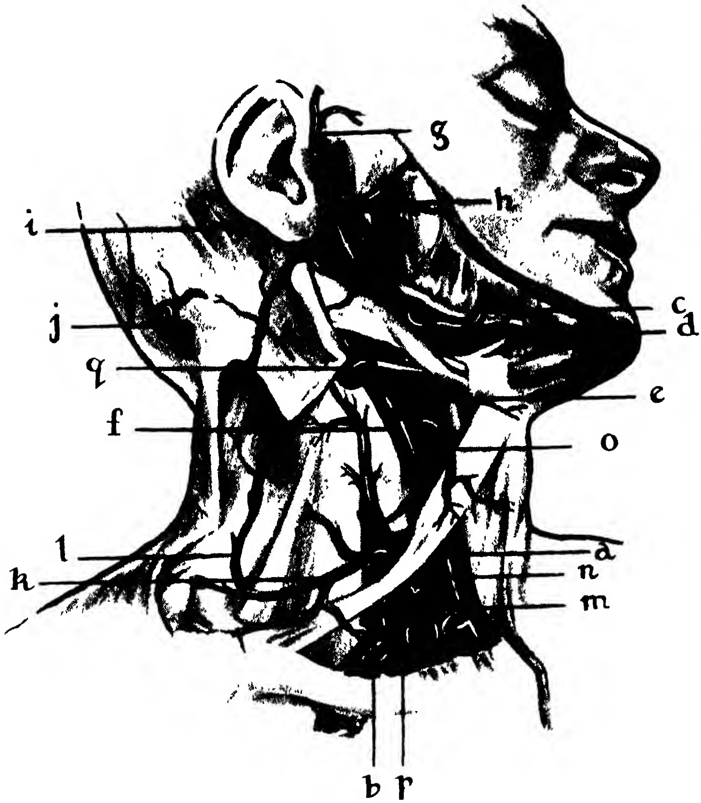


Fig. 117.—Circulus Arteriosus.

Arteries shown: *a*, Vertebral. *b*, Anterior spinal. *c*, Basilar. *d*, Pontine arteries. *e*, Superior cerebellar. *f*, Posterior cerebral. *g*, Posterior communicating. *g*. Anterior cerebral. *i*, Anterior communicating. *j*, Middle cerebral. *k*, Internal carotid. *l*, Arterial circle.

Circulus Arteriosus.—This is the name given to the system of blood supply to the brain; it is the map which demonstrates the arterial geography of the inside of the skull and is best understood by reference to the diagram (Fig. 117).

The Pulmonary Artery.—As we already know, this large trunk performs quite a different function from that of the systemic circulation. It takes the venous blood from the right ventricle to the lungs. First it travels upwards in front of the aorta, then passes below the arch, where it divides into the right and left branches, one for each lung. In the lungs it divides into



ARTERIES OF THE NECK. RIGHT SIDE.

a, Common carotid. *b*, Subclavian. *c*, External maxillary. *d*, Submental. *e*, External carotid. *f*, Internal carotid. *g*, Superficial temporal. *h*, Transverse facial. *i*, Posterior auricular. *j*, Occipital. *k*, Transverse cervical. *l*, Ascending branch of transverse cervical. *m*, Vertebral. *n*, Inferior thyroid. *o*, Superior thyroid. *p*, Transverse scapular. *q*, Internal jugular vein (cut).

minute branches spreading like a network over the surfaces of the lung spaces until the smallest capillaries are reached.

The Principal Veins

The venous system differs from the arterial system in that the vessels are more numerous and they anastomose with each other to a much greater extent, giving the impression of a wide-mesh network surrounding the limbs. Veins may be divided into a deep group and a superficial group. The deep group comprises the veins which accompany the great arteries (venae comites), and they are usually duplicated. The superficial group lies in the superficial fascia, and its vessels do not accompany arteries. They are the drainage system of the skin and its underlying tissues, and are easily made out by their blue lines shining through the skin. In many cases e.g. in the arm and leg, the veins stand out prominently, especially when pressure is made above. In the interior of the skull the membranes of the brain enclose venous blood in spaces called sinuses, which have their special methods of circulation described below. Otherwise all veins begin by the joining up of fine capillaries, and as the vessel proceeds towards the heart it gathers up tributaries until it becomes a large trunk like the aorta. The nomenclature of the deep veins is similar to that of their companion arteries, thus the radial and ulnar veins unite to form the brachial vein, which in turn becomes the subclavian vein, which empties its blood into the innominate vein. Thereafter a new system of names is given, the vein leading into the right atrium being called the superior vena cava. Similarly, the veins which drain the external and internal areas of the skull unite to form the main trunk—the internal jugular vein of the neck—or terminate in smaller veins, the external jugular, the anterior jugular or the vertebral vein. All reach the innomnate vein, which unites with its fellow of the opposite side to become the superior vena cava, which is about 3 inches long.

Sinuses of the Head.—The complex membranes which surround the brain enclose certain pockets, or sinuses, which contain venous blood and which for all practical purposes may be regarded as much enlarged veins. The superior sagittal sinus corresponds to the upper groove which divides the brain into two hemispheres. The inferior sagittal sinus occupies the free border of the membranous partition which dips into this groove. It opens into the straight sinus, which is a channel passing backwards and downwards towards the back of the brain. It should be noted that the superior sagittal sinus opens into another sinus called the transverse sinus, which runs outwards in two portions, on either side along the membranous shelf supporting the brain

(tentorium cerebelli). The straight sinus, however, also empties into the transverse sinus, selecting the right or the left according to which is available, after the superior sinus has determined its course. The transverse sinus is also called the lateral sinus, and is of importance in ear disease, as it may become dangerously affected when middle ear disease is acute. These lateral sinuses terminate in the internal jugular vein. There are several other sinuses anteriorly and inferiorly such as the cavernous sinus beside the sella turcica, but they are of subsidiary importance to nurses. Eight emissary veins pass from the sinuses to veins outside the skull, using various bony canals.

Drainage of the Trunk and Lower Limbs.—The head and upper extremities are drained by veins which end in the right atrium by the superior vena cava. The lower limbs are dealt with similarly, except for the fact that the termination is the inferior vena cava, which reaches the right atrium from below. The veins of the foot (deep group) run into the anterior and posterior tibial veins, which in turn become the popliteal, femoral and external iliac veins. The pelvis is drained by the tributaries of the internal iliac vein. The external iliac and the internal iliac veins unite to form the common iliac vein at the junction of the sacrum and ilium. The common iliac veins unite to form the large trunk of the inferior vena cava at the 4th lumbar vertebra, and as this great vessel passes up the back of the abdomen on the right of the aorta, it receives lumbar, testicular (or ovarian), renal, suprarenal, phrenic and hepatic veins. Grooving the back of the liver, the inferior vena cava passes through the centre of the diaphragm and ends at the right atrium (Plate VIII).

The Azygos Veins.—These are a group of veins which act as subsidiary drainage channels to serve the area intervening between the superior and inferior vena cava. The chief is the vena azygos major, and one, or two, others may be present; these veins drain certain parts of the abdomen and most of the thoracic area.

The Portal System.—This is one of the most important and most interesting parts of the venous system. Starting with the superior and inferior mesenteric veins, the splenic veins and the gastric veins, which drain the digestive tract, the portal vein is formed. This vein goes into the liver, dividing there into 2 branches and finally subdividing into minute capillaries or sinusoids. When the portal capillaries are reached, the blood is then passed on to the hepatic veins, and ultimately reaches the inferior vena cava.

The Pulmonary Veins.—These are 4 in number, beginning in the lung capillaries and forming 2 main channels from

each lung. The 4 pulmonary veins open into the left atrium, bringing back the freshly oxygenated blood from the lungs.

The Superficial Veins.—This section has been left to the last, as it is probably most important from the nurse's point of view. All the superficial veins reach the heart by joining one of the main trunks already described, but their function and position just underneath the skin give them special prominence, and certain veins must be recognized. In the upper extremity, the network of veins in the back of the hand becomes 4 distinct venous trunks conveying the blood upwards. These vessels are as follows (from lateral to medial aspect):

1. The accessory cephalic vein (radial);
2. The cephalic vein (median);
3. The median antibrachial vein (anterior ulnar);
4. The basilic vein (posterior ulnar) (Fig. 118).

The cephalic vein gives off an important branch at the bend of the elbow (median cubital vein) which ultimately joins the basilic vein, and which is a favourite site for intravenous transfusion. It was formerly known as the median basilic vein. The accessory cephalic vein proceeds to the lateral side of the biceps and joins the cephalic vein. The median antibrachial vein joins the basilic vein at a point just in front of the medial epicondyle of the humerus. Thus there are two main venous trunks passing up the upper arm—the cephalic laterally and the basilic medially; both empty their blood into the axillary vein.

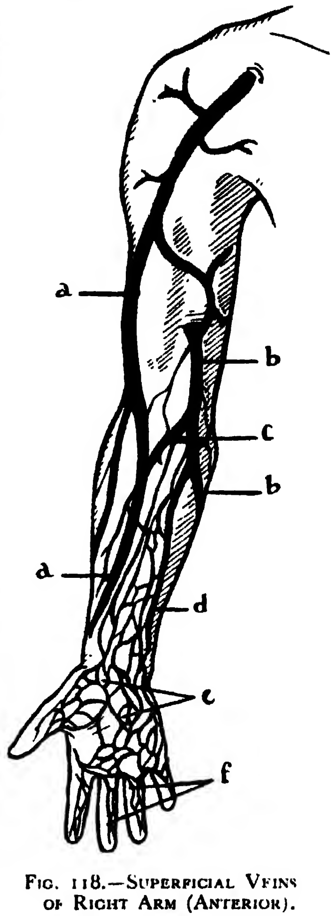


Fig. 118.—Superficial Veins of Right Arm (Anterior).

a, Cephalic vein. *b*, Basilic vein. *c*, Median cubital vein *d*, Median antibrachial vein *e*, Dorsal venous network *f*. Dorsal digital veins

In the lower extremity, there are 2 outstanding groups, the chief being the long saphenous vein. This vessel is the great superficial drainage channel of the medial aspect of the leg and

thigh, passing from the dorsum of the foot upwards over the calf, along the medial side of the knee joint, and so upwards and for-

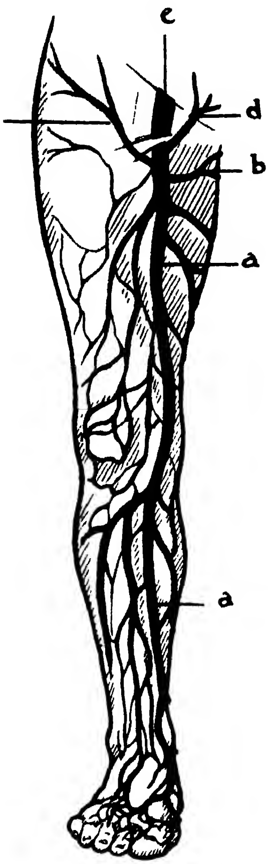


FIG. 119.—SUPERFICIAL VEINS OF RIGHT LEG (ANTERIOR).

a, Long saphenous vein. *b*, Superficial external pudendal vein. *c*, Superficial iliac circumflex vein. *d*, Superficial epigastric vein. *e*, Femoral vein.

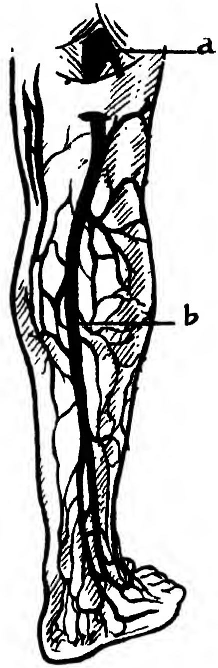


FIG. 120.—SUPERFICIAL VEINS OF RIGHT LOWER LEG (POSTERIOR).

a, Popliteal vein. *b*, Short saphenous vein and branches.

wards to a point called the saphenous opening, 1½ inches below the inguinal ligament, at which it joins the deep femoral vein.

In its course it receives tributaries like a great river. The short saphenous vein begins on the outer side of the foot, and passing behind the lateral malleolus, runs upwards on the back of the leg, receiving branches from that area and finally joins the popliteal vein between the heads of the gastrocnemius muscle (Fig. 120). The long saphenous vein is noted from a surgical point of view, as it is frequently the site of varicose veins, a condition of twisting and enlargement of the veins and their valves, the result of back-pressure and long continued strain. A glance at the diagram will confirm the importance of the function of this long column of blood stretching from the foot to the groin, and provided with valves at intervals (Fig. 119).

CHAPTER 11

THE CIRCULATORY SYSTEM—PHYSIOLOGY OF THE CIRCULATION

THE SYSTEMIC AND PULMONARY CIRCULATIONS. THE PORTAL CIRCULATION. HOW THE BLOOD CIRCULATES. THE PULSE AND THE CARDIAC CYCLE. THE HEART SOUNDS. HOW THE RHYTHM OF THE HEART IS GOVERNED. THE WORK OF THE HEART. BLOOD PRESSURE. THE NERVOUS CONTROL OF THE HEART. VASOMOTOR CONTROL.

VERY little was known about the circulation of the blood until the middle of the seventeenth century, when William Harvey proved that the blood moved in a circle. The work of this great man was the starting point of many investigations with results of far reaching importance in physiology, but even today research is still disclosing many new factors. We divide the circulation into 3 parts viz. the systemic circulation, the pulmonary circulation and the portal circulation.

The Systemic and Pulmonary Circulations

If we marked a red blood corpuscle and were thus enabled to follow its course and check its stages as it moves through the body, we should find that beginning in the left ventricle it leaves the heart by the aorta, passing over the semilunar valve. Taking the arterial road, it reaches one of the terminal arterioles, and so passes into a capillary, where its progress slowed, like a ship in a canal. At this point it gives up its oxygen and the plasma fills up with carbonic acid gas. Then the veins begin, and the corpuscle is sucked back through them to the large veins and so to the right atrium. The trapdoor of the tricuspid valve opens, and the blood escapes through to the right ventricle, whence it is forced by muscular contraction to the pulmonary artery and to the limits of the pulmonary capillaries which surround the air chambers, or alveoli, of the lungs. Here the corpuscle takes in a full load of oxygen, while the plasma delivers up its carbonic acid gas, and the blood becomes bright red again. The capillaries merge and become the pulmonary veins, which enlarge and unite to form the 4 pulmonary veins, in one of

which the blood cell returns to the left atrium. Once again the mitral valve opens and admits the corpuscle to the left ventricle, where it began its tour.

The portion of the cycle which concerns the passage of the blood through the main mass of the body is called the systemic circulation, and that which involves the lungs, the pulmonary circulation. It is very difficult to say where one begins and the other ends, so it is better to study both together.

The Portal Circulation

In two cases, the circulating blood is passed through a gland before it returns to the right atrium. The renal circulation passes through the kidneys and is very simple, but the more important of the two is the portal circulation, which is an accessory stream filtered by the liver. The fine capillaries of the stomach, intestines, spleen and pancreas ultimately become the portal vein, which passes through the liver and so to the heart by the method described on p. 164. This is discussed in more detail on p. 204.

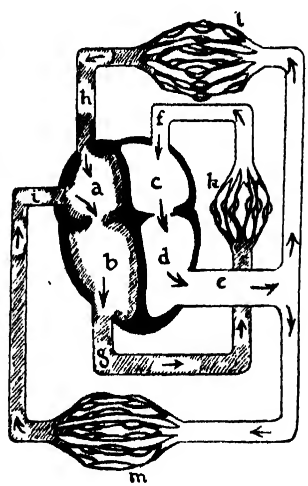


FIG. 121.—DIAGRAM SHOWING THE CIRCULATORY SYSTEM.

a, Right atrium. *b*, Right ventricle. *c*, Left atrium. *d*, Left ventricle. *e*, Aorta. *f*, Pulmonary vein. *g*, Pulmonary artery. *h*, Superior vena cava. *i*, Inferior vena cava. *k*, Area of interchange in the lungs. *l*, Area of interchange in the head and upper limbs. *m*, Area of interchange in the abdomen and lower limbs.

How the Blood Circulates

The fundamental condition which ensures the circulation of the blood is difference of pressure. All fluids rise to certain heights in tubes depending upon the force behind them, or alternatively, the removal of the air pressure above them. A vacuum is a space devoid of air; if it were connected by a valve with a tube containing a fluid, the fluid would quickly be sucked up when the valve was opened. In the human body the heart acts by alternately contracting and expanding its chambers, so that on the one hand we have a driving force exerted and on the other a suction power. The result is that the arterial blood is forced in spurts into the systemic circulation and

steadily sucked back by the venous system, which is provided with additional valves along its course. The valves of the heart, especially the atrioventricular valves, are all-important in the prevention of back flow and in keeping the blood flowing in one specific direction (Fig. 121). There are 2 main factors governing the flow of the blood: 1. the power of the heart muscle; 2. the inherent elasticity of the blood vessels.

The Pulse and the Cardiac Cycle

What is commonly called the pulse is but one example of a rhythm which is constantly going on in the body at any part through which an artery runs. When the doctor investigates the pulse he takes as his sample the radial artery at the wrist; the vessel is most superficial there, and if the area is kept under constant observation for a minute or two, it will be found that normally pulsation occurs at a regular rate, so many beats a minute. We confirm this by feeling the artery delicately with our fingers, at the same time making observations of the quality of the vessel wall, the amount of thickening, the size of the artery, the force and the character of the rhythm. All this gives us an indication of the state of the heart's action and is comprised in the ceremony of " taking the pulse." Nurses are not often expected to do more than observe the number of beats per minute; this is discussed in Section V, Chapter 6. By means of an instrument called the sphygmograph, commonly used by physicians, a tracing on paper can be made of the action of the pulse. It explains the meaning of the pulse wave, which travels along the arteries from the left ventricle and produces certain impressions on the wall of the artery at regular intervals. The pulse beats are produced a fraction of a second after the heart has contracted. A further improvement is the polygraph, which records the changes in the internal jugular vein when the atrium fills up and empties. Normally, however, the estimation by the fingers is sufficient; the average number of beats per minute in an adult is 72. A woman's heart beats more quickly than a man's. In the first year, the rate may be 120 without serious import, and gradually the rate drops to 72. Old people may suffer from slowing of the pulse, a rate of 60 being quite common. The pulse also varies temporarily and for different periods, according to the mental state of the person involved, the amount of hard physical exercise (e.g. in athletes) and certain conditions of life.

The Cardiac Cycle.—Within the heart itself there is an established routine, resulting in the regular output of a constant volume of blood passing into the aorta and into the pulmonary artery. This routine is known as the cardiac cycle. Two distinct

phases are found. First there is a period during which th muscle contracts on the chambers; this is known as systole Secondly there is a period of dilatation; this is known as diastole

The cycle begins by the contractions of the atria, these acting together; immediately after this the ventricles contract simultaneously; then follows a pause, during which the muscles gradually relax until systole starts again. Roughly the time occupied in each cardiac cycle is $\frac{3}{4}$ second; the atrial plus the ventricular systolic phase is slightly longer than the diastolic phase. The routine in each of the chambers is as follows:

Atrial Diastole.—The blood is pouring in from the large veins on both sides, the chambers expanding until the tricuspid and mitral valves open and allow the blood to pass to the ventricles.

Atrial Systole.—The contraction is like a squeezing action of the muscle, passing from above downwards. The ventricles have been filled up by leakage through the atrioventricular valves, and the last volume from the atrium makes it necessary to get rid of the excess in the ventricle.

Ventricular Diastole.—As mentioned above, the ventricles begin to fill before auricular diastole is complete and by the time the auricular systole is finished the ventricles are ready for the next stage.

Ventricular Systole.—This describes the contraction of the ventricular muscle and the emptying of the chambers into the two arterial trunks through the gates of the semilunar valves. The atrioventricular valves are closed, preventing the escape of blood back to the atria. The left ventricle is the more powerful of the two as would naturally be expected when we consider how much it has to do in the driving of the blood through the systemic circulation.

The closing of the semilunar valves can be understood easily if we imagine that a certain volume of blood is being forced into the aorta, this causing slight eddies which effectively shut the cusps as soon as the ventricular pressure drops owing to the relaxed muscle. The closure of the semilunar valves is a distinct accent in the cycle.

The Heart Sounds.—By listening over the area of the heart with the ear close to the chest wall, definite sounds can be heard. Doctors usually employ an instrument called the stethoscope, which nowadays consists of a chest-piece, or receiving cup, from which two rubber tubes lead to closely fitting ear-pieces (Fig. 122). Originally, however, the stethoscope was a trumpet-like appliance made of wood or metal, and one ear only was used. Two sounds are heard. The first or systolic beat is slightly muffled and prolonged; it is caused by the overcoming of the resistance in the full ventricle, and is an index of the

muscular power of the ventricle; it stops just before the end of the systolic phase. There is a very short pause, followed by the second, or diastolic, beat, which is short and loud, coinciding with the swinging out of the semilunar valves as they close the orifice of the aorta. Phonetically these sounds are represented by the words *Lūbb-dŭp*. A longer pause follows the second sound, but it must be remembered that the whole cycle occurs in less than a second. The rate of the heart can be ascertained by counting the number of second sounds per minute. If there is any semilunar valve disease, the second sound may be quite soft, and thus we are able to diagnose many defects. Four sounding areas are fixed as being most perfect for the hearing of the sounds. The area of the apex beat is a well known landmark on the chest; it is situated in the 5th left intercostal space, 3½ inches from the middle line, and is the spot at which the tip of the contracting ventricle comes up against the chest wall. The first sound is best heard just internal to the apex beat. The second sound is most audible at the 2nd right costal cartilage, where the aorta is nearest to the chest wall.

FIG. 122. BINAURAL STETHOSCOPE, NOW IN GENERAL USE. (*By courtesy of the Surgical Manufacturing Co. Ltd., London.*)

How the Rhythm of the Heart is Governed.—It has been proved conclusively that the heart muscle possesses some peculiar property of rhythmical contraction which exists in the muscle and not in the nerves. This is called myogenic rhythm and depends upon several important factors.

The Sinuatrial Node.—This is a portion of the heart near the entry of the superior vena cava. It is chiefly composed of finely specialized cardiac muscle, and it acts as the governor or pacemaker of the heart.

The Atrioventricular Node.—This node, of similar type, is to be found also in the right atrium. From it there springs the structure described below.

The Atrioventricular Bundle.—Passing from the atrioventricular node, certain fibres spread over the ventricular septum. This, the second part of the impulse tract, is known as the atrioventricular bundle (formerly bundle of His). The bundle passes to the apex of the heart.

Evidence of heart communications is still incomplete, but it is certain that all the above nodes and bundles, devoid as they may be of nervous connection, nevertheless act in concert to bring about rhythmic action of the heart. When, for instance, there is anything wrong with the atrioventricular

bundle, the cardiac cycle is interrupted, a condition known as heart block.

Electrical Investigation of the Heart Rhythm.—Great improvement in the elucidation of the physiology of cardiac action has been made by the introduction of the electrocardiogram. By a rather complicated system of recording the electrical impulses made by the beating heart (electrocardiograph), information is obtained as to the condition of the muscle and of the nodes and bundles. The findings are charted and can be studied in detail, a specific pattern being demonstrated for each type of defect.

The Work of the Heart

The heart goes steadily on, its aim being to maintain a regular supply of oxygen for the tissues. It is known that the heart can increase its rate, depending upon the needs of the body, and in this way its sensitiveness is of vital importance to health. The cardiac output depends upon the amount of venous blood going into the atrium, and the output may vary apart from rate. This is important, as it explains the adaptability of the heart to sudden calls of excitement, emotion and exercise. Thus in normal circumstances, about 5 litres of blood are pumped out in a minute, but in hard exercise, 30 litres may be passed on. The property of the heart in this capacity is called the cardiac reserve; this is very important in all diseases, since it may be used up in order to compensate for valvular defects and may result in breathlessness and inability to move. The heart is always able to compensate itself by overgrowth of the muscle (hypertrophy) but this has its limits. What the heart has to contend with is the overcoming of blood pressure (see below) in the arteries, and in the production of a certain amount of speed or velocity of blood flow.

Blood Pressure

Blood pressure has become a subject of almost daily conversation with everybody; medical science has demonstrated its importance as an index of the health of the individual in a most conclusive way.

The arteries possess a certain amount of resistance owing to the elastic tissue in their coats. The heart in contracting sets up an original pressure; this is added to the pressure which exists in the arteries. As we pass from artery to capillary and from capillary to vein, the pressure gradually diminishes until it is at its lowest in the atrium and ventricle during diastole. This ensures the flow of blood, because a liquid always runs from a higher to a lower pressure. It also explains why blood spurts from an artery and oozes from a vein. The velocity of the blood is

greatest in the aorta; at the capillaries we find the maximum number of vessels, which, possessed of very slight resistance, cause the rate of blood flow to slow down considerably. When the veins begin, their bed is very large, and velocity is still very low; as the vein increases in size, the velocity becomes higher, but since the arteries are about half the size of the accompanying veins, the velocity of the veins is never higher than that of the arteries.

Peripheral resistance is another factor which must be taken into consideration. The arterioles are very minute vessels leading into the capillaries and are therefore spread like a network in all directions. Their elastic tissue is sufficient to keep up a constant tone in the vessels, so that the blood is passed through a type of lock before it reaches the capillary bed. The capillaries are now known to have a certain amount of contractility, and no doubt they exert a slowing-down influence on the blood corpuscles, which constantly pass in single file through them.

We can sum up the main factors in maintaining the blood pressure as 1. the power generated by the heart muscle; 2. the peripheral resistance and the elastic coats of the arteries; 3. the amount of blood.

The above do not necessarily assist the return of the blood to the heart. Here we must take into consideration the pressure of the muscles on the superficial and deep veins, the respiratory movements and the action of the diaphragm, and the sucking power of the empty atria, whose action may be suitably imitated and made clear by sucking up water with an old-fashioned fountain pen filler or eyedrop applicator, and watching the effect.

FIG. 123.—SPHYGMOMANOMETER.
(By courtesy of the Surgical Manufacturing Co. Ltd., London.)

Blood pressure will be increased by 1. increased power of the heart; 2. increased peripheral resistance; 3. increased volume of blood; 4. contraction of the capillary bed. A decrease will occur when a directly opposite condition exists. This is very important in all physical conditions. The blood pressure in man is recorded by an instrument called the sphygmomanometer, many varieties of which are used daily in the wards and sickrooms. The principle is the obliteration of the pulse by a constricting band and the registration of the pressure required to do this, by a column of mercury or an aneroid indicator. Two pressures can

be estimated, the systolic and the diastolic. In a healthy young adult, the systolic pressure should be anything from 110 to 135 millimetres of mercury (usually recorded as "mm. Hg.") when the person is in the sitting posture, and sometimes a convenient way to estimate the normal pressure according to age is to add the number of years to 100, but it must never be forgotten that blood pressure is a dangerous thing to dogmatize about, and excitement, worry, overwork and strain may affect it considerably, as well as organic disease of the vessels. The diastolic pressure is more difficult to estimate, but it is the more important of the two. It varies from 70 to 90 mm. Hg. in different individuals, and when it goes above 90, it is a sign of considerable abnormality, temporary or otherwise (Fig. 123).

The Nervous Control of the Heart

Despite the demands of nervous, mental or physical energy, the heart must maintain a steady supply of blood appropriate to the condition. The circulation must be efficient to meet every emergency. We know that the heart is governed by the pacemaker, but certain nerves act like the reins to a horse's head—they allow the heart to speed up for a little and then pull it up. In this way every extraordinary demand is met. The two actions are called cardio-accelerator mechanism and cardio-inhibitory mechanism respectively.

The Cardio-accelerator Mechanism.—This is contained in the sympathetic nerves which run to the heart and surround the coronary vessels in plexuses. Most probably these fibres have origin in the lower part of the brain, which is stimulated by loss of blood or shortness of breath. The messages reach the brain centres by the sensory nerves from all over the body.

The Cardio-inhibitory Mechanism.—The vagus nerve contains specialized fibres which keep the heart in control. The centre in the medulla receives messages from many parts, and may be responsive to a blow over the stomach, as in boxing. The vessels themselves send depressor impulses. Many drugs act in the same way and are employed extensively in medicine.

Vasomotor Control.—It is definite that the tightening up or slackening of the arteries is due to two sets of fibres running in the nerves and known respectively as vasoconstrictors and vasodilators. They are controlled from the lower part of the brain, and are influenced by various states, including concentration of carbonic acid gas, the presence of chemicals and so on. It is obvious that one set of fibres is antagonistic to the other, and this permits the finest adjustments in the capacity of the arterioles, depending upon the conditions which have to be met.

CHAPTER 12

THE LYMPHATIC SYSTEM

LYMPHATIC VESSELS. THE LYMPH CAPILLARIES. THE LYMPHATICS. LYMPHATIC GLANDS. LYMPHATIC DUCTS. THE IMPORTANCE OF LYMPHATIC GLANDS. THE COMPOSITION OF LYMPH. HOW LYMPH IS FORMED. THE FLOW OF LYMPH.

THE blood, in its circulation, passes through the fine capillaries, where it is slowed down. This allows the exudation of a certain clear fluid to pass through the walls, and so to bathe the tissues. The name of this fluid is lymph; it is rich in all the nourishing elements required by the tissues, and its function is to keep the protoplasmic cells constantly bathed in this medium. When it has delivered its supply, it collects the waste products and returns to the blood stream by fine vessels known as lymphatics, which empty mainly into a trunk called the thoracic duct. The thoracic duct is the main lymphatic vessel of the body; it discharges its contents into the blood stream at the junction of the left internal jugular and left subclavian veins. There is a special lymphatic drainage system (the right lymphatic duct) serving the right side of the head and neck, the right lung, right side of the heart, right side of the thorax and the right upper extremity. The termination of this duct is at the angle formed by the right subclavian vein with the right internal jugular vein (Fig. 124).

Lymphatic Vessels

The Lymph Capillaries.—Beginning at the origin of the lymphatic system, we find that a lymphatic commences by the formation of a network of vessels very like the capillaries, except that the lymphatic vessels are larger and more variable in size; they are provided with valves at regular intervals. It is certain that there is no direct communication between the lymphatic capillary and the tissue spaces; most authorities agree that the lymphatic vessel in its capillary form has the power of absorbing the waste lymph through its walls, which consist of one layer of endothelial cells sticking closely together. In the lining of the small intestine, specialized lymphatics, called lacteals, exist. These have a specific purpose in the digestion and are discussed later (pp. 180, 207).

The Lymphatics.—When the lymphatic trunks are formed, they have a beaded appearance, caused by the regularity of the valves, and they resemble thin-walled veins. These vessels pass through certain important lymphoid aggregations known as lymphatic glands. The importance of these glands cannot be overestimated.

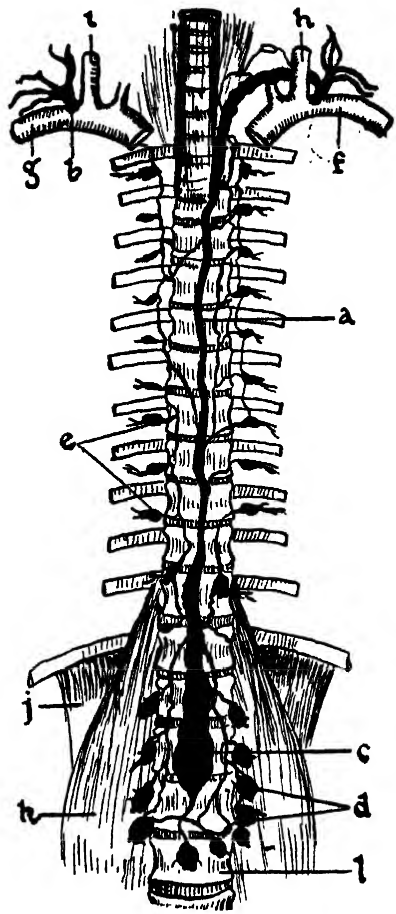


FIG. 124.—THORACIC DUCT AND RIGHT LYMPHATIC DUCT.

a, Thoracic duct. *b*, Right lymphatic duct. *c*, Cisterna chyli. *d*, Lumbar lymph glands. *e*, Posterior intercostal glands. *f*, Left subclavian vein. *g*, Right subclavian vein. *h*, Left internal jugular vein. *i*, Right internal jugular vein. *j*, Quadratus lumborum m. *k*, Psoas major m. *l*, 4th lumbar vertebra

Lymphatic Glands

These may occur singly, but generally they are found in groups. The individual gland is a firm, compact organ, varying in size from that of a hemp seed to that of a haricot bean. They are found along the course of the large blood vessels, at the root of the lungs, on the posterior wall of the abdomen, in the thorax, and prominently at the root of the neck, the axilla and the groin.

Structurally, a lymphatic gland is composed of a strong capsule of fibrous tissue, which sends beams, or trabeculae, inwards, thus splitting up the gland into open spaces containing the lymphoid tissue which is the essential substance of the gland. When a gland is cut open it is seen to be composed of 2 areas viz. an outer and lighter area called the cortical part, and an inner and darker area—the medullary part. The cortical portion has the larger spaces between

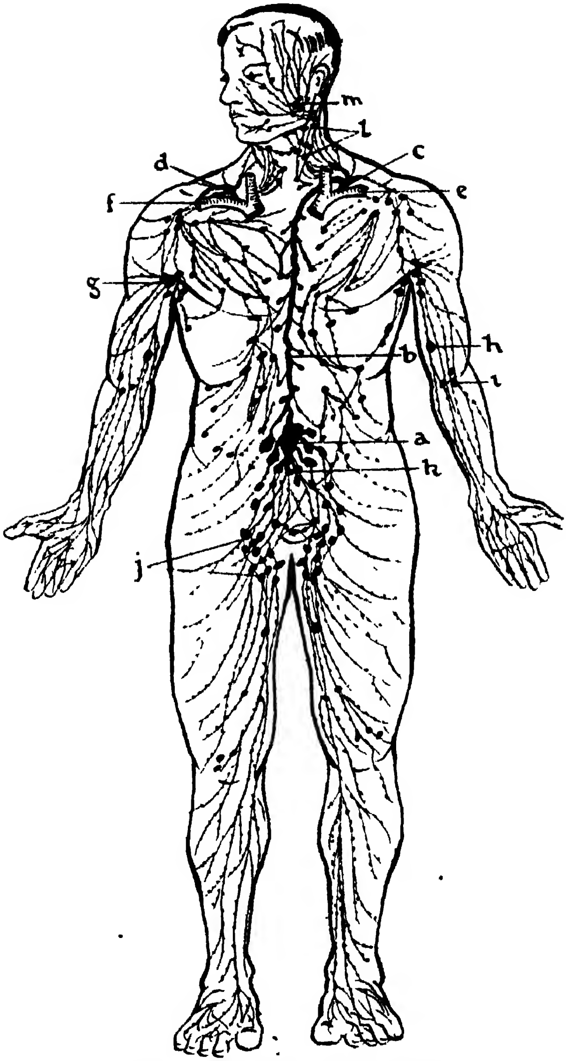


FIG. 125.—DIAGRAM SHOWING THE GENERAL LYMPHATIC SYSTEM.

a, Cisterna chyli. *b*, Thoracic duct. *c*, Left lymphatic duct. *d*, Right lymphatic duct. *e*, Left subclavian vein. *f*, Right subclavian vein. *g*, Axillary lymph glands. *h*, Supratrochlear lymph gland. *i*, Cubital glands. *j*, Inguinal glands. *k* Lumbar glands. *l* Cervical glands. *m*. Parotid glands

the trabeculae, and known as alveoli, while the medullary portion is more dense with fibrous beams. On microscopical examination of the lymphoid tissue in the alveoli, it is found that the lymphoid matter is surrounded by channels containing fine transverse threads. These are known as the lymph paths, and are almost free of lymph corpuscles. Lymphatic glands as a rule have a convex surface and a concave surface or hilum. The lymph going to the gland (afferent system) enters the convex border by the afferent vessel, which splits into several finer trunks opening into the lymph path. After circulating through the lymph path, the fluid emerges at the hilum by the efferent system, which consists of several tributaries running into a single lymphatic vessel. The blood vessels which supply the substance of the gland with nourishment pass also by the hilum. The lymphocytes which are massed in the alveoli are exactly the same as those found in the blood (see Plate VI).

Lymphatic Ducts.—As already mentioned, the thoracic duct is the main lymphatic vessel of the body. It starts at a point in front of the 2nd lumbar vertebra at a pond-like dilatation into which the lumbar glands pour their lymph, the receptaculum or cisterna chyli (Fig. 125). The duct then runs up on the front of the spine, passes through the diaphragm at the aortic opening, and veering to the left, arches over the subclavian artery in the thorax, to join the left subclavian vein at the root of the neck. The thoracic duct receives the lymph from all parts of the body, except the right arm, right lung and the right side of the head, neck and thorax. These areas have a clearance system of their own ending in the right lymphatic duct, which is only ½ inch long and which opens into the right subclavian vein (Figs. 124, 125).

The Importance of the Lymphatic Glands.—It is not necessary to describe fully the systems of lymphatic vessels which drain the limbs and the various areas of the body, and which are shown in the illustrations (Figs. 124 and 125). Lymph is discussed below in some detail, as it is important physiologically. The lymphatic glands are anatomically and surgically of great importance and they come into the picture of almost every disease, since they enlarge or become affected by overwork or by actual infection from the area which they serve. Thus the glands of the neck are prominent in tuberculosis and cancer, while the glands of the axilla and groin swell up prominently in sepsis or other disease of the hands and feet respectively. Lymphoid tissue occurs here and there in specialized solitary patches, such as the tonsils and in certain parts of the small intestine, where they are known as Peyer's patches. The serous membranes cover the abdominal organs and other structures;

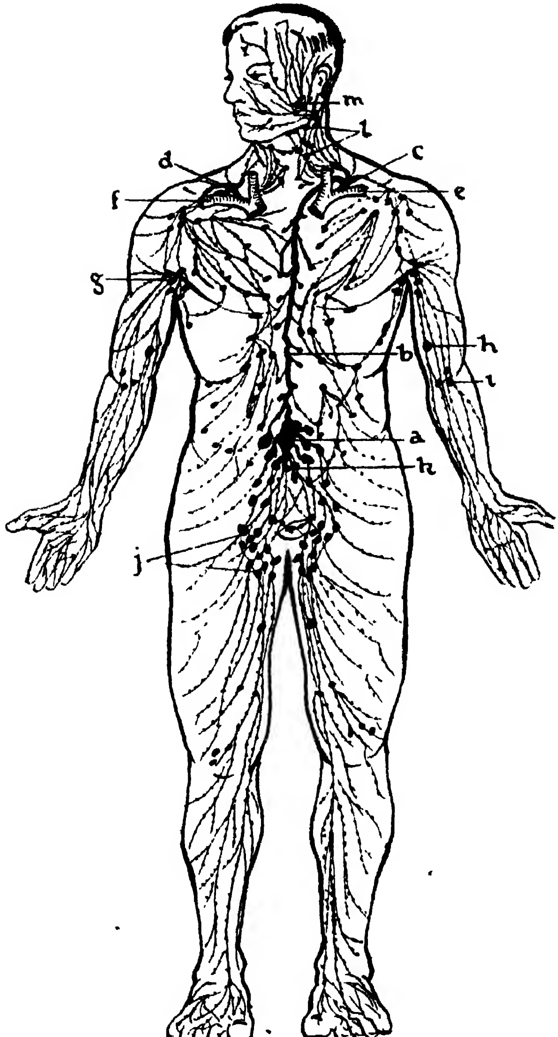


FIG. 125.—DIAGRAM SHOWING THE GENERAL LYMPHATIC SYSTEM.

a, Cisterna chyli. *b*, Thoracic duct. *c*, Left lymphatic duct. *d*, Right lymphatic duct. *e*, Left subclavian vein. *f*, Right subclavian vein. *g*, Axillary lymph glands. *h*, Supratrochlear lymph gland. *i*, Cubital glands. *j*, Inguinal glands. *k* Lumbar glands. *l* Cervical glands. *m*. Parotid glands

the trabeculae, and known as alveoli, while the medullary portion is more dense with fibrous beams. On microscopical examination of the lymphoid tissue in the alveoli, it is found that the lymphoid matter is surrounded by channels containing fine transverse threads. These are known as the lymph paths, and are almost free of lymph corpuscles. Lymphatic glands as a rule have a convex surface and a concave surface or hilum. The lymph going to the gland (afferent system) enters the convex border by the afferent vessel, which splits into several finer trunks opening into the lymph path. After circulating through the lymph path, the fluid emerges at the hilum by the efferent system, which consists of several tributaries running into a single lymphatic vessel. The blood vessels which supply the substance of the gland with nourishment pass also by the hilum. The lymphocytes which are massed in the alveoli are exactly the same as those found in the blood (see Plate VI).

Lymphatic Ducts.—As already mentioned, the thoracic duct is the main lymphatic vessel of the body. It starts at a point in front of the 2nd lumbar vertebra at a pond-like dilatation into which the lumbar glands pour their lymph, the receptaculum or cisterna chyli (Fig. 125). The duct then runs up on the front of the spine, passes through the diaphragm at the aortic opening, and veering to the left, arches over the subclavian artery in the thorax, to join the left subclavian vein at the root of the neck. The thoracic duct receives the lymph from all parts of the body, except the right arm, right lung and the right side of the head, neck and thorax. These areas have a clearance system of their own ending in the right lymphatic duct, which is only ½ inch long and which opens into the right subclavian vein (Figs. 124, 125).

The Importance of the Lymphatic Glands.—It is not necessary to describe fully the systems of lymphatic vessels which drain the limbs and the various areas of the body, and which are shown in the illustrations (Figs. 124 and 125). Lymph is discussed below in some detail, as it is important physiologically. The lymphatic glands are anatomically and surgically of great importance and they come into the picture of almost every disease, since they enlarge or become affected by overwork or by actual infection from the area which they serve. Thus the glands of the neck are prominent in tuberculosis and cancer, while the glands of the axilla and groin swell up prominently in sepsis or other disease of the hands and feet respectively. Lymphoid tissue occurs here and there in specialized solitary patches, such as the tonsils and in certain parts of the small intestine, where they are known as Peyer's patches. The serous membranes cover the abdominal organs and other structures;

they are well supplied with lymphatic elements, which drain the areas through special openings leading to the lymph channels and which are called stomata.

The Composition of Lymph

To a certain extent lymph is similar to the blood plasma. It is weaker in nitrogenous elements and its specific gravity is about 1015, but when it stands it becomes clotted to form a loose colourless mass of fibrin. There is more of the salty, chloride element in lymph, and it naturally contains more waste products than does the blood. Carbonic acid gas and urea predominate. Lymph is frequently enriched with its characteristic corpuscles by passing through glands. After a meal, the lymph in the thoracic duct is found to be milky; this variety is known as chyle, its condition being due to very minute globules of fat absorbed from the intestine during digestion. The fine lymphatics leading from the intestines also show a milky white coloration when digestion is at its height. For this reason they are called lacteals. Lymph may vary in strength, depending upon the blood. If a severe amount of bleeding has occurred, the watery elements of the lymph immediately become transferred to help in the making good of the volume of the blood. On the other hand, when the blood is added to by injections or similar extra fluid volumes the lymphoid tissues become more saturated. The whole process can be likened to a sensitive valve which governs the volume of the blood and uses the lymph as its reserve.

How Lymph is Formed.—Since lymph is very important as a repair factor in injury, it is necessary to know how it is produced. Two systems may be used. The first is that in which the capillary pressure is increased. If there is increase of the blood fluid, more will exude from the capillary wall. The second is commonly experienced. If there is damage to the capillaries, as occurs in almost every minor injury, in certain skin diseases and so on, the walls become more permeable and allow increase of lymph supply, which is essential to repair of the tissues. Again, the tissues may demand more lymph in order to dilute their waste products if they have been actively engaged. Strenuous games involve maximum work from muscles, which attract lymph to their cells and often become swollen and painful. Rest and massage usually bring speedy relief, which proves that the tissues are temporarily waterlogged.

The Flow of Lymph.—There is no mechanism like the heart, so far as human beings are concerned, for the propelling of the lymph, which is helped on its way by several different methods. Of these the muscle and other tissue pressures act by hastening

the current, which is further assisted by the numerous valves. It is also thought that there is some contractile power in the walls of the lymphatics. The movements of the respiration influence the thoracic duct in much the same way as they affect the large veins.

CHAPTER 13

THE SPLEEN

STRUCTURE OF THE SPLEEN. THE SPLEEN PULP. THE FUNCTIONS OF THE SPLEEN.

THE spleen is associated with the vascular system and therefore is dealt with apart from the abdomen, but it is an abdominal organ. It is about 5 inches long, 3 inches wide and 1½ inches thick, and is situated in the upper part of the left side of the

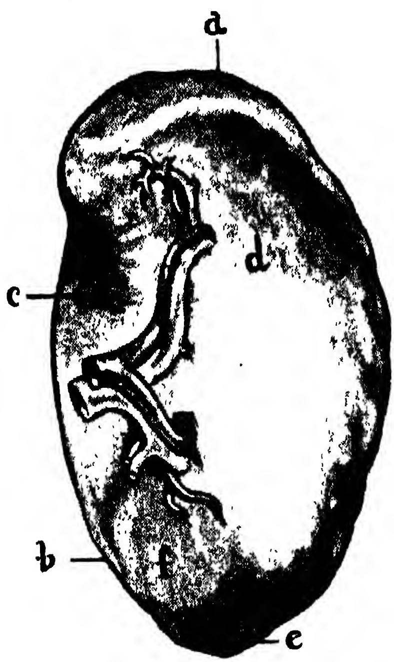


FIG. 126.—THE SPLEEN. INFERIOR ASPECT.

a, Anterior border. *b*, Posterior border. *c*, Renal surface. *d*, Gastric surface. *e*, Colic surface. *f*, Pancreatic surface.

cavity, deeply placed under the 9th, 10th and 11th ribs. Its relative position can be more carefully described when the other abdominal organs are studied; meanwhile all that need be learned

about the neighbours of the spleen is that the organ is in contact with the diaphragm, the left side of the stomach, the left kidney and the extremity of the pancreas. It is very dark purple in colour, weighs about 7 ounces and is rather brittle, owing to its loose structure. The blood supply is derived from the splenic artery, which is a branch of the coeliac artery. The splenic vein, which is a tributary of the portal vein, drains the spleen (Fig. 126).

Structure of the Spleen.—Enveloping the organ is a serous coat, which is a portion of the peritoneum. Below this the spleen proper is found. It has a capsule composed of a considerable amount of fibrous tissue, elastic tissue and smooth muscle. As in the lymphatic glands, the capsule sends in processes (trabeculae) which subdivide until a network of supporting tissue is formed. In the intervening spaces the spleen pulp is contained.

The Spleen Pulp.—On analysis of the dark red-brown material from the spleen, we find both red and white cells in various stages of growth or degeneration. These lie on a fine reticular membrane made up of fibres from large branching cells. This network also receives the capillaries, which are the terminations of the vessels entering the spleen at the hilum or concave surface. These capillaries thus communicate direct with the pulp. This is an important point; it means that all the old and broken down cells of the blood are off loaded at one spot and that new and active cells are immediately taken into the blood stream.

There are many similarities between the spleen and the lymphatic glands. On the sheaths of the fine thread-like branches of the splenic artery are circular pale spots, giving a granular appearance to the pulp. They are the Malpighian corpuscles, in construction almost the same as a lymphoid nodule.

To a certain extent the flow of blood through the spleen is expedited by the smooth muscle contractions of the capsule and the trabeculae.

The Functions of the Spleen.—Five distinct properties are possessed by the spleen as described below.

1. *Formation of White Blood Corpuscles.*—This is to be expected, since the spleen resembles closely the lymphatic glands. The splenic vein takes away a large proportion of lymphocytes. Further, if the spleen is removed, the lymphatic glands become more numerous and do more work.

2. *Formation of Red Blood Corpuscles.*—In early life, the spleen manufactures red blood cells; this is also proved by removal of the spleen, when the red marrow increases.

3. *Destruction of Red Blood Cells.*—The reddish-brown colour of the spleen suggests the presence of iron. As a matter of fact, the spleen is the depot for the breaking up of decadent red corpuscles, whose elements—iron, cholesterol, lecithin in

particular—are separated out and presumably re-used in the formation of new erythrocytes.

4. *Manufacture of Uric Acid.*

5. *Storing of Blood.*—During digestion, there is always a maximum supply of blood to the abdominal organs. Apparently the spleen also acts as a sub-station controlling the supplies for a particular period. It does not have the rhythm of the heart but it can contract and expand with great speed. It becomes permanently enlarged in many diseases, of which malaria is the best known. In such conditions, the tip can be felt bulging below the costal margin.

So far as the erythrocytes are concerned, the spleen is a depot for basic reserves. As in a battle troops must be ready in thousands to go into action as a mass, so the red blood cells are held in readiness in the spleen, which can release them in quantities at any time and so regulate the number in the circulation. This is demonstrated when from some cause there is oxygen deficiency (haemorrhage, strenuous exercise); the organ contracts and forces the erythrocytes into the circulation. The spleen can also manufacture bilirubin from the pigments deposited in its tissues; this is complementary to the amount normally produced in the liver.

CHAPTER 14

THE RESPIRATORY SYSTEM

HOW OXYGEN IS DELIVERED TO THE TISSUES. HOW CARBONIC ACID GAS IS DISCARDED. ANATOMY OF THE RESPIRATORY SYSTEM. THE LARYNGEAL MUSCLES. THE LUNGS. THE PLEURA. SUNDRY IMPORTANT FACTS ABOUT THE RESPIRATORY SYSTEM. THE MECHANISM AND PROCESS OF RESPIRATION. INSPIRATION AND EXPIRATION. TYPES OF RESPIRATION. THE PROCESS OF RESPIRATION. THE VOLUME OF AIR BREATHED. THE COMPOSITION OF AIR. THE CONTROL OF RESPIRATION. TISSUE RESPIRATION. THE METHOD OF GAS EXCHANGE. GENERAL REACTIONS TO TISSUE NEEDS.

THE fundamental action of the process of respiration can be described in a few words: it is the method whereby oxygen gas is taken up by the tissues, and carbonic acid gas is got rid of. Admittedly there are several ways in which this can be done and some of the processes are rather intricate, but all unite to keep the process of combustion going on in the body at a constant rate.

How Oxygen is Delivered to the Tissues.—The supply of oxygen is present everywhere in fresh air. By muscular action of bellows type, the tiny lung chambers, of which there are thousands, are distended regularly with air. Fine blood vessels spread over these chambers, and the blood in them selects a certain and constant amount of oxygen, sufficient for the needs of the tissues; then the blood carries the oxygen to every cell in the body.

How Carbonic Acid Gas is Discarded.—The veins return from the tissues full of blood which has lost part of its oxygen and has taken up carbonic acid gas. By the pulmonary artery, which we have already studied, the venous blood is pumped to the lungs, reaching the little air chambers by a method similar to that of the arterial network. Here the carbonic acid gas is given up, stored up in the chambers until they are full, and then expired as one volume when the lungs are allowed to collapse.

Anatomy of the Respiratory System

In its passage from the outside atmosphere to the fine chambers of the lungs, air follows a definite route, going through the following structures mentioned below.

1. *The Anterior Nares.*—This is the anatomical term for the external opening of the nostrils.

2. *The Nasal Canals.*—If reference is made to the bony structure of the nose (p. 45), it will be noted that the interiors of the two nasal canals are very irregular, with deep fissures. This has a purpose. The large area exposed is covered with a mucous membrane plentifully supplied with blood vessels, and the cells are of the type known as ciliated epithelial cells (see p. 8). When the air passes over this membrane it is not only warmed; the cilia trap the particles and fix them in a layer of mucus, and they are either moved on to the back of the throat or discharged by the nostrils.

3. *The Posterior Nares.*—The exit from the back of the nose, leading to the nasopharynx.

4. *The Nasopharynx.*—Into this part, there opens the pharyngo-tympanic tube (Eustachian tube) from the ears; it is the upper part of the pharynx, which is described in full later with the digestive system.

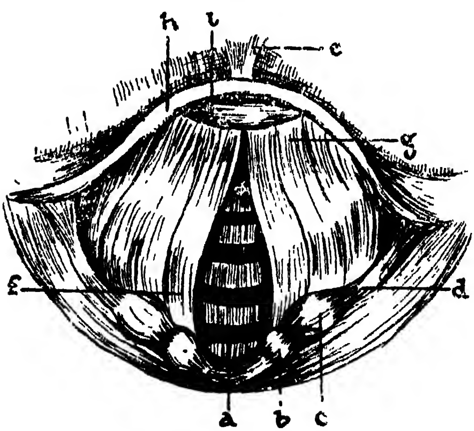


Fig. 127.—The Larynx. Interior View.

a, Trachea. *b*, Cuneiform cartilage. *c*, Corniculate cartilage. *d*, Aryepiglottic fold. *e*, Median glosso-epiglottic fold. *f*, Vocal fold. *g*, Vestibular fold. *h*, Epiglottis. *i*, Tubercle of epiglottis.

5. *The Larynx.*—After passing through the pharynx, the air chooses the tube which lies in front of the gullet; the upper part of this tube is known as the larynx, or voice-box. It is the prominent structure we feel on the front of the throat, popularly termed the "Adam's Apple." This structure is very resistant, being composed of cartilage. It lies at the level of the 4th, 5th and 6th cervical vertebrae, and is made up of the thyroid cartilage, which (as the Adam's Apple) juts out

like the prow of a ship; the cricoid cartilage, which is immediately below the thyroid, and forms a complete ring, somewhat wider posteriorly; and the arytenoid cartilages, which are two pyramid-like structures rising up from the cricoid cartilage behind and forming the back wall of the larynx. The chief strong connecting ligaments between the various constituents of the larynx are the thyrohyoid membrane, the lateral thyrohyoid ligament, the cricothyroid ligament and the capsular ligament. Two other pairs of small cartilaginous bodies are associated with the arytenoid cartilages viz. the corniculate cartilages, or cartilages of Santorini, and the cuneiform cartilages or cartilages of Wrisberg.

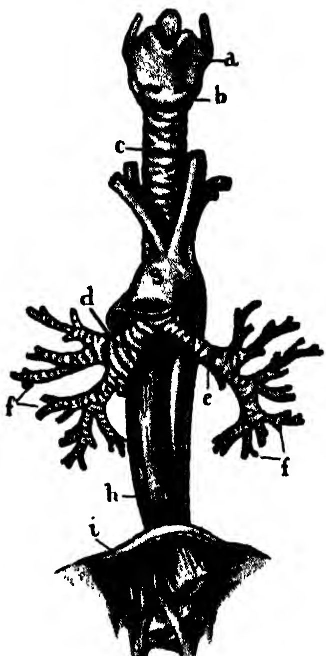


FIG. 128.—THE TRACHEA, BRONCHI AND OESOPHAGUS.

a, Thyroid cartilage. *b*, Cricoid cartilage. *c*, Trachea. *d*, Right bronchus. *e*, Left bronchus. *f*, Bronchial tubes. *g*, Aorta. *h*, Oesophagus. *i*, Diaphragm.

The epiglottis is one of the most important structures of the body. It is the trapdoor of the larynx, closing over the open canal when food is swallowed, and remaining open when air is taken in. It is shaped like a leaf, the tip being fixed to the thyroid cartilage and the base being free and broad to fit over the orifice of the air tube.

Inside the larynx we find the vocal cords or folds, stretching from the thyroid cartilage in front to the arytenoid cartilages behind, and dividing the larynx into an upper chamber called the vestibule and a small lower chamber leading to the circular rim of the trachea. The false cords or vestibular folds are two crescentic folds of mucous membrane lying above the true cords. The latter become narrowed as they stretch across, and leave a small chink called the rima glottidis. Between the upper and lower cords is a fossa known as the ventricle of the larynx, while the recess on either side above the false cords is full of mucous glands and is called the laryngeal pouch. Voice is produced by the vibration of the true cords, which are acted upon by several muscles (Fig. 127).

6. *The Trachea.*—A cylindrical tube made up of about 20 incomplete rings of cartilage, completed by muscle fibres of the trachealis muscle, joins the larynx to the bronchi, described below. The trachea is about 4½ inches long and 1 inch wide, and runs from the level of the 6th cervical vertebra to the upper border of the 5th dorsal vertebra. It is lined throughout by ciliated epithelium. Behind is the gullet; in front and at the sides are the great vessels and nerves of the neck. The blood supply of the trachea is derived from branches of the subclavian artery, mainly the inferior thyroid artery. The nerve supply is provided by branches of the vagus and recurrent laryngeal nerves. The autonomic nervous system also sends sympathetic fibres (see p. 270).

7. *The Bronchi.*—The trachea splits into two by bifurcating into the right and left bronchus, each of which is constructed on similar lines to the trachea (Fig. 128). The bifurcation is to be found at the level of the upper border of the 5th thoracic vertebra, opposite to the line marking the union of the manubrium and gladiolus of the sternum. The bronchi divide and subdivide, losing their complete cartilaginous rings at the third subdivision, and finally become minute bronchioles, which lead into the air chambers (or alveoli) of the lungs. The right bronchus is wider than the left, and is 1 inch in length; the left bronchus is twice the length of the right bronchus and runs more obliquely. The blood supply is provided by the bronchial arteries, which spring from the descending thoracic aorta, or from the upper posterior (aortic) intercostal arteries.

The Laryngeal Muscles.—There are many muscles acting on the larynx, some of which are associated with the vocal cords, and some with the epiglottis. The most important are described in the table given below.

Name.	*Origin.*	*Insertion.*	*Remarks.*
Cricothyroid	Cricoid cartilage	Thyroid cartilage	Tightens vocal cords
Crico-arytenoideus posterior	Cricoid cartilage	Arytenoid cartilage	Opens the glottis
Crico-arytenoideus lateralis	Cricoid cartilage	Arytenoid cartilage	Closes the glottis
Arytenoideus transversus	One arytenoid cartilage	Its fellow opposite	Closes back of glottis
Thyro-arytenoideus	Thyroid cartilage	Arytenoid cartilage	Slackens vocal cords

Nerve supply: External and recurrent laryngeal nerves.

The Lungs.—On either side of the cavity of the thorax, occupying almost the entire space, is a very spongy structure called the lung (see Plate VII). The lungs are composed of thousands of little air cells; to the touch they are elastic and obviously full of air. In outline, the lungs are like cones with the apex fitting into the narrow upper part of the thorax, and the base lying on the diaphragm. The right lung differs from the left lung in that it is subdivided into 3 lobes while the left has only 2. Each lung appears to have a stalk —the hilum, formed by the bronchi, the vessels and the other structures which enter and leave the lungs by this single highway. Just as the bronchi subdivide, so the lobes subdivide, forming lobules, loosely joined by areolar tissue and which in turn divide into air cells. The terminal bronchioles divide as shown in the diagram (Fig. 129), ending in infundibula from which the finest air pouches seem to bud off. The alveoli, as these are called, have a very delicate function. They are like miniature balloons, with walls consisting of a single layer of pavement epithelium. The blood capillaries spread out all over the outer surface of these alveoli, so that we are dealing with two closely applied and very delicate membranes separating the blood from the air in the lung chambers, and thus allowing diffusion of gases to go on smoothly (Fig. 129).

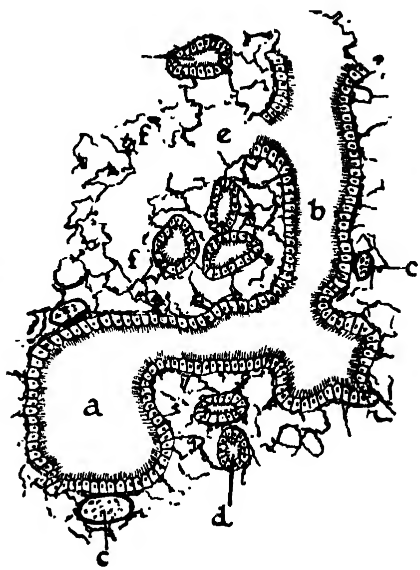


FIG. 129.—SECTION THROUGH LUNG TISSUE. *a*, Bronchus. *b*, Bronchiole. *c*, Cartilage plate. *d*, Bronchioles cut across. *e*, Atrium. *f*, Infundibulum.

The Pleura.—The lungs, like the heart, are contained in a serous bag, consisting of two layers of membrane known as the pleura. The portion next the lung is called the visceral pleura, and is closely applied like a fine varnish, dipping into the fissures and grooves. At the hilum of the lung, this membrane reflects on to the inner surface of the thoracic wall. There is a very

small space between the parietal and visceral layers, but it is sufficient to hold the requisite amount of serous fluid for the lubrication of the bag and so permits frictionless motion when the lungs are in action. Pleurisy is an inflammation of these layers, and the signs of creaking are typical of the dryness of the area.

Sundry Important Facts about the Respiratory System.—The cilia are continued as far as the smallest bronchioles, being present even after the columnar cells have given place to cubical cells.

The cartilage gradually diminishes from the trachea to the smallest tubes, in which cartilage is represented by small scattered flakes only.

The mucous glands are everywhere beneath the mucous membrane; they pour out their secretion into the bronchial lumina. In various states of "catarrh," there is too much mucus in the bronchioles, therefore it is passed upwards by the cilia, and finally coughed out.

The blood supply is twofold: 1. The pulmonary artery, which takes the blue blood to be arterialized from the heart to the alveoli; 2. the bronchial artery, which supplies the actual structure and tissues with nourishment, accompanied by the bronchial veins, which return the venous blood in the usual way.

The nerve supply is by the vagus and sympathetic.

The lungs are elastic, and if air or fluid is allowed into the pleural bag, the organs recoil considerably, shrivelling up to leave a space between them and the thoracic wall. This is often taken advantage of in disease of the lung when artificial pneumothorax is established. Normally, it is the pressure of the atmosphere on the inside only of the lungs that keeps them distended.

The surface of the lungs on the inside is about 120 square yards.

Lung tissue is very light. In the normal adult, a disease-free portion of lung floats easily when it is removed and placed in a basin of water.

The Mechanism and Process of Respiration

Inspiration and Expiration.—Respiration is a cycle, akin to the rhythm of the heart. Inspiration is the intake of air; expiration is the expulsion of the waste gases. One phase follows the other without a pause, but there is a very slight break between the complete respirations.

It must never be forgotten that the lungs themselves have no active part in the mechanism; they are entirely passive, filling

up or emptying in obedience to the muscular changes taking place in the thorax.

Inspiration demands an increased area surrounding the lungs, therefore the preliminaries are contraction of the diaphragm, which increases the space vertically, and the raising of the ribs by the appropriate muscles—the external and internal intercostal muscles and the levatores costarum and serratus posterior superior.

With regard to expiration, relaxation of all the above muscles causes a diminution of the chest space, resulting in the setting up of pressure inside the alveoli which forces the air out. Expiration is the elastic recoil of the expanded lung.

Extraordinary Respiration.—When special efforts are required, auxiliary forces are available. Anyone familiar with the embarrassment of patients suffering from breathlessness knows that the facial muscles and the muscles of the neck, chest and the back come into play when there is a need for forced inspiration. In forced expiration, which is necessary for speaking, singing, coughing, sneezing, playing wind instruments and so on, the elastic recoil is not enough, and other factors are brought into use such as the abdominal muscles and the depressors of the ribs. A cough is a short forced expiration performed in order to propel a quantity of mucus over the larynx. A yawn or a sigh, on the other hand, indicates a prolongation of inspiration, and apart from mental fatigue, grief or emotion, in disease it means severe bleeding or a weak heart. Hiccough, or hiccup, is the result of uncontrollable spasms of the diaphragm which by its sudden sharp action forces the air noisily through the larynx.

Were it not for the integrity of the pleural sac, the lungs would collapse. The importance of the pressure within the pleura cannot be overestimated. Injuries or diseases of the pleura affecting the pressure within the sac prove that the filling and emptying of the lung are entirely dependent on the condition of the air in the pleural space.

Types of Respiration.—There are 3 distinct varieties of breathing. The child uses his diaphragm more than any of the other muscles (the abdominal type); the adult male adds to this a movement of the chest and sternum (the inferior costal type); while the female uses the upper muscles more than the lower (the superior costal type).

The Process of Respiration.—The rate of respiration varies according to age and sex. Females breathe more quickly than males. In infants, the respirations may amount to 40 per minute, but the normal adult rate is about 18 per minute. The ratio of the normal pulse to the normal breathing is therefore 4:1. Since respiration is very easily influenced by the demands

of the organism for more, or less, oxygen, it is governed by a sensitive mechanism which increases or diminishes the rate as necessary e.g. in sickness, exercise, emotional stress or rest.

The Volume of Air Breathed.—Even after forced expiration, the lungs are not free of air; what is left is called residual air, and amounts to about 1,300 cubic centimetres.

Normally at each inspiration a certain quantity of air is drawn into the lungs, and the same amount is expired. This is called tidal air and it amounts to about 500 cubic centimetres. It is clear that the air in the alveoli must therefore always be mixed; to a certain extent the supply of air for the alveoli is in the form of varied "layers." The air which comes out of the nose or mouth is not a pure specimen of the alveolar air.

Complemental air is the air taken in when a forced inspiration is made over and above the tidal air; it amounts roughly to 1,600 cubic centimetres.

Supplemental air is the air supplementary to the tidal air when a forced expiration is made; the volume of this is also 1,600 cubic centimetres.

If a person takes the maximum inspiration and follows it by the maximum expiration, the amount breathed out will be the sum of the tidal, complemental and supplemental air i.e. about 3,700 cubic centimetres. This is the index of the vital capacity of the chest.

The Composition of Air.—Considering the changes that go on at various parts of the respiratory system, it is to be expected that the air constituents will alter in their proportions according to the place at which the specimen is tested.

The atmospheric air contains nearly 21 per cent of oxygen, 79 per cent of nitrogen and ·04 per cent of carbonic acid gas.

The expired air contains about 16 per cent of oxygen, 80 per cent of nitrogen and 4 per cent of carbonic acid gas. It is heated and saturated with water vapour.

The air in the alveoli contains about 14 per cent of oxygen, 80 per cent of nitrogen and 6 per cent of carbonic acid gas.

The Control of Respiration.—Three factors influence the respiration viz. the respiratory centre, the vagus nerves and the amount of carbonic acid gas in the blood.

The respiratory centre is said to consist of 2 parts, an inspiratory and an expiratory portion, both situated in a comparatively diffuse area of the brain spreading above the pons and into the medulla. The inspiratory centre is much more active than the expiratory. The influence of this centre is such that impulses are sent regularly to the diaphragm, over the "wires" of the phrenic nerves, which cause that muscle to contract and relax 15-18 times a minute.

Messages are undoubtedly passed up to the brain from the alveoli by means of the vagus nerve fibres, and they have certain limiting influences on the centres. These vagus stimulations are closely associated with the third factor, discussed below.

If there is much demand for oxygen in the tissues, and therefore an unusual production of carbonic acid gas, the latter not only saturates the blood; it acts as a chemical stimulant to the respiratory centres, resulting in an increased rate of breathing. The chemical and nervous factors are very closely reciprocated.

Tissue Respiration

So far we have dealt only with external respiration, in which the breathing is conducted through a tube leading to the outside air. As we mentioned at the beginning, however, there are other ways of gaseous exchange viz. through the tissues. We have followed the atmospheric air as far as the alveoli, where the oxygen is accepted by the haemoglobin, and carried by it as oxyhaemoglobin to every cell actively at work in the body. Here the oxygen is " fed " to the protoplasm according to the demand, and the carbonic acid gas and some water, compounded as sodium bicarbonate, are taken up by the returning blood and thus go by the veins to the heart. Tissue respiration is really the fundamental mechanism of gas exchange.

The Method of Gas Exchange.—When a capillary reaches, say, a muscle cell, the action is thought to be a simple process of diffusion, oxygen passing through one way and carbonic acid gas in the reverse direction. The lymph, everywhere as a medium, assists the gases to make the change-over. Everything depends upon the oxygen pressure of the blood in the capillaries. This should always be greater than that in the muscles, and it so happens that the greater the muscle action, and therefore the greater the carbonic acid gas, the higher the resultant oxygen pressure of the capillary. Glands need more oxygen than muscles and connective tissue appears to require least oxygen of all.

General Reactions to Tissue Needs.—It is evident that the whole aim of the respiratory system, external and internal, is to provide a steady supply of new oxygen to the tissues. Asphyxia results when the supply of oxygen is cut off completely, and its symptoms need not be described, as they are well known. Before asphyxia occurs, however, the body has called up all its reserve forces in an effort to keep the delivery rate constant. Thus breathlessness, or dyspnoea, is the effort to increase oxygen supply by increase of the number of respirations per minute, and it is found in diseases, after exercise of different degrees or in life

at high altitudes. There are opposite conditions (e.g. caisson pressures) in which people may have to work at increased oxygen concentration. In certain circumstances the human being can become accommodated to abnormal conditions. This is the process which is at the root of " second wind " and the state of training of the athlete

CHAPTER 15

THE DIGESTIVE SYSTEM—THE ALIMENTARY TRACT

THE ALIMENTARY CANAL. THE MOUTH. THE LIPS. THE TEETH. THE GUMS. THE TONGUE. THE PALATE. THE TONSILS. THE PHARYNX. THE OESOPHAGUS. THE STOMACH. ANATOMICAL FEATURES OF THE STOMACH. THE SMALL INTESTINE. THE LARGE INTESTINE. THE VERMIFORM APPENDIX. THE RECTUM AND ÁNUS ORGANS ASSOCIATED WITH THE ALIMENTARY CANAL. THE SALIVARY GLANDS. THE LIVER. THE HEPATIC DUCTS AND GALL-BLADDER. THE PANCREAS. THE GASTRIC AND INTESTINAL GLANDS. THE PERITONEUM. THE OMENTA. THE MESENTERIES. THE PELVIC PERITONEUM.

We have learned how the gas which is essential for the slow combustion going on in the body reaches the cells, and now we must study how the fuel itself is dealt with. As with oxygen, a steady supply of a certain proportion of the necessary elements required to make good the losses of the tissues must be maintained. The fuel in the rough, so to speak, is the food as it appears in various forms on our plates. Before that food reaches the cells, however, it has to undergo a long and complex process of refinement and simplification. We have spoken of our body as a furnace: no stoker would think of shovelling variegated coal on his fire; he knows that to get a steady heat the coal must be screened and trimmed until the pieces are all of one size and quality. Therefore we, as stokers of the body, must know how our food is treated and prepared for its ultimate work in the tissue cell. The system concerned with the assimilation of food is the Digestive System, which consists of a long tube of varying calibre, connecting the mouth with the anus. It is assisted by several important glands which cooperate closely with the process of digestion by pouring secretions through ducts into the tube at certain established points

The Alimentary Canal

The Mouth.—The first part of the alimentary canal is represented by the mouth, an oval cavity divided up by the jaws,

teeth and gums into an outer vestibule, and an inner part containing the tongue, inner aspects of the jaws and teeth, and the palate, called the cavity of the mouth. This cavity leads into the pharynx.

The Lips.—The muscular structures round the lips have already been studied (pp. 107–109). The fleshy portions consist of loose tissue covered by thin mucous membrane controlled by these muscles, and are used for speech and expression. Originally, however, we must regard the lips as having been primarily intended for prehension of food at a time when their cosmetic and other subsidiary functions were not so much in evidence as they are today.

The Teeth.—Civilization and modern culture have proved the necessity of giving the maximum attention to the teeth. Two sets of teeth grow on the jaws: 1. the temporary teeth; 2. the permanent teeth. The points made on pp. 45 and 46 may be enlarged here.

The Temporary Teeth.—This is the first, or milk, set of teeth, 20 in all. The first two (lower) incisors erupt when the child is about 6 months old; these are followed by the upper 2 incisors, and then by 2 more lower incisors and 2 more upper incisors in order, until at the end of the first year the child should have 8 central teeth, 4 above and 4 below. Very soon after, the first double teeth appear, the molars, one on each side above and below, and at a year and a half, the pointed canine teeth cut through the gums at the side of the lateral incisors. Finally, a second set of molars erupts, one on each side above and below. Therefore at the age of 2, a child should have a complete set of temporary teeth, 10 above and 10 below, and consisting of 4 incisors, 2 canines and 4 molars in each jaw. It is important to know something about these dental matters, for mothers pay great attention to the cutting of the teeth and the nurse is frequently catechized about them. It is quite usual to have deviations from the normal teething order.

The Permanent Teeth.—At the age of 6, the child gets his first permanent teeth; a molar erupts (the "six-year molar") just behind the last of the temporary teeth. A little later, the 4 central incisors of the temporary set are replaced by those of the permanent set, and towards the end of the 8th year the lateral incisors appear. By the end of the 9th year, 4 new teeth are due, the first bicuspids, which lie between the molars and canines, and a second set of 4 appears shortly afterwards. At about 11 years, the permanent canines are cut; a set of second molars erupts at 12 years; the wisdom teeth may appear between the 17th and 21st year. The whole set thus consists of the following in each jaw: 4 incisors, 2 canines, 4 bicuspids and 6 molars, a total of 16.

Structure of a Tooth.—The front teeth are specialized for biting, the back teeth for grinding and chewing. All have more or less the same structure, but we shall take for our example a molar tooth (see p. 46, Fig. 39). It will be noted that this has a crown, neck and root. The crown is the part above the gum; it is covered by a very hard substance, the enamel. The neck is the part flush with the gum; the root is tightly wedged in a socket of the alveolus bone. The main fabric of a tooth consists of dentine, which is harder than bone and not unlike it in construction. In the centre of each root is a soft tissue containing connective tissue, several blood vessels and lymphatics and a nerve; this is known as the pulp—it lies in the pulp cavity. This is the toothache area and the cause of most of the discomforts of dentistry.

The Gums.—This tissue needs no description. The gums are familiar as the cushions of the teeth, moulding them to the alveolar margins and maintaining a firmness and resilience like soft indiarubber. They are covered by a mucous membrane with stratified epithelium and are very vascular, bleeding easily on injury. Their numerous pockets and corners often harbour microbes and give rise to debilitating disease when the daily toilet of the teeth is neglected.

The Tongue.—The muscles of the tongue have already been described (p. 112), and this organ is fully dealt with later, when the special senses are discussed (p. 282). As a part of the alimentary system, the tongue is the vehicle which passes the food into the gullet. It is the chief occupant of the cavity of the mouth, roughly triangular in shape and somewhat like a leaf with its base fixed to the hyoid bone. It can be protruded for about half its length, as it is also fixed to the floor of the mouth. The fraenum linguae is a fold of mucous membrane which can be felt underneath the tongue. It does its work after the fashion of the mooring rope; sometimes the latter is too short, resulting in the condition of "tongue-tie."

The Palate.—In dealing with the skull, we found that there is a hard plate of bone forming the roof of the mouth. This is covered by a small amount of connective tissue and by mucous membrane. The palate in this situation is called the hard palate, but it is prolonged by a flap or curtain of soft muscle tissue covered by mucous membrane, which is easily seen at the back of the mouth forming the entrance porch to the pharynx. This is the soft palate; its curtains are united by a fleshy tag which dips down almost to the tongue, and which is known as the uvula (Plate XIII). These curtains are prolonged downwards in two folds enclosing the tonsils. The folds are called the pillars of the fauces, the anterior forming the palatoglossal arch, and the

posterior the palatopharyngeal arch. When we look into the mouth we see clearly soft palate, uvula, pillars of the fauces and tonsils guarding the rear portion of the mouth, which is called the pharynx.

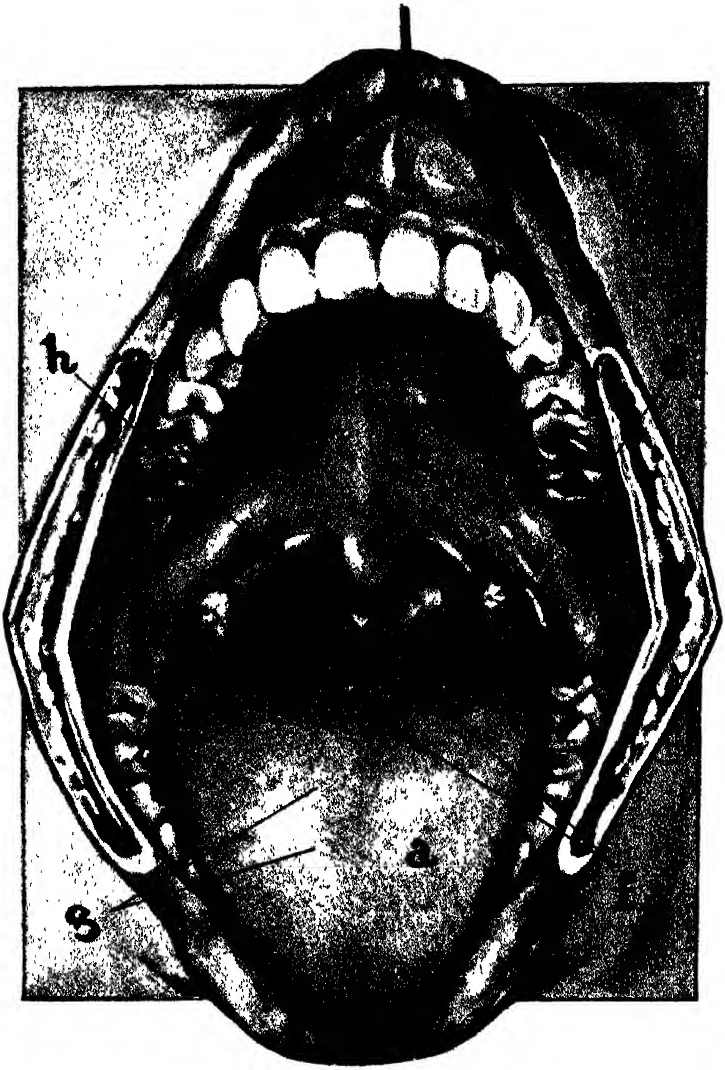
The Tonsils.—These were mentioned in passing when we dealt with the lymphatic system. They are lymphoid structures of great value to the individual, as they are apparently possessed of great protective powers. Each tonsil is like the half of the seed of a walnut in size and character. Normally they do not bulge beyond the pillars of the fauces but they are so sensitive to any disease that they are often found to be enlarged.

The Pharynx.—When we look right at the back of the mouth we see the posterior wall of the pharynx, a funnel-shaped passage leading down to the gullet, which it joins at about the level of the 6th cervical vertebra. The pharynx can be divided into 3 portions. The first is the part mentioned above—the oral pharynx, flanked by the tonsils and the pillars of the fauces. The second is the nasopharynx, which lies behind the posterior nares, receives the pharyngo-tympanic tubes, and is the site of the adenoid tissue. It is the area behind the curtain of the soft palate, and if the index finger is put behind the uvula it will lie in the nasopharynx. The third part is the laryngeal pharynx, which is situated behind the larynx and leads into the gullet.

Structure of the Pharynx.—The pharyngeal muscles have already been dealt with (p. 112); all that remains is the consideration of the lining of the walls. Spread over the muscles is a layer of fibrous tissue forming the fibrous coat. Covering the fibrous coat and forming the lining of the pharynx is the mucous coat, similar to that of the other structures above.

The Oesophagus.—Commonly called the gullet, this part of the alimentary tract is a tube leading from the pharynx to the stomach. It is about 9 inches long, and enters the stomach at the cardiac orifice, to the left of the middle line. As it passes down, it lies on the vertebral column and behind the trachea, piercing the diaphragm at a special opening in its muscular mass. The muscles of the gullet are in two layers—an outer longitudinal layer and an inner circular layer, these constituting the muscular coat. The mucous membrane forms the mucous (lining) coat. Two areolar coats are also found, one between the mucous and muscular coats and one on the outside of the muscles, enveloping the gullet completely. There are not any cartilaginous rings in the gullet.

The Stomach.—A great deal has been learned about the stomach as a result of x-ray investigation. Formerly the position and shape of the stomach were not clearly defined; now we know much more about its normal features. We must regard it



CAVITY OF THE MOUTH.

a, Tongue. *b*, Glossopalatine arch. *c*, Uvula. *d*, Pharyngopalatine arch. *e*, Palatine tonsil. *f*, Papillae vallatae. *g*, Papillae fungiformes. *h*, Isthmus faucium.

primarily as a dilatation of the alimentary canal, an elaboration of the simple tube which is found in the lower animals. It occupies the centre part of the upper abdomen, but also extends to the left, lying immediately below the diaphragm. Its length is about 12 inches; at its broadest part it is 4 inches. It is the main organ of digestion and is not a sagging bag, but a powerful muscular organ, consisting of 4 coats: 1. outer, 2. muscular, 3. submucous, 4. mucous.

The outer or serous coat is derived from the peritoneum and covers almost the whole of the external surface.

The muscular coat has 3 layers, longitudinal, circular and oblique, from without inwards. The longitudinal layer extends from the oesophagus; the circular layer is specialized at the exit of the stomach to form the pyloric valve.

The submucous coat is composed of loose areolar tissue between the muscular coat and the mucous coat.

The mucous coat is epithelial and is discussed later. When the stomach contracts, this coat is thrown into folds, generally referred to as rugae.

Anatomical Features of the Stomach.—It is now known that the upper end of the stomach is much higher than the lower end; indeed, most x-rays show the stomach rather like the letter J (Fig. 130). It varies its position slightly, but when a person is lying flat on his back the shape alters considerably. The capacity of the stomach is roughly 6 pints.

The fundus is the name given to the upper end; it bulges out suddenly from the gullet. The lower end is called the pylorus; it lies close to the liver and gallbladder. The lower border is the greater curvature; the upper border the lesser curvature. The entrance is known as the cardiac orifice; the exit as the pyloric orifice, containing the pyloric valve described above. The main body of the stomach is marked off from the pyloric portion by a fissure on the lesser curvature—the incisura angularis.

In association with the stomach are the oesophagus at one end and the duodenum at the other; the latter marks the beginning of the small intestine proper. The main relations of the stomach are as follows. Taking first the anterior surface, which also looks upwards, this is in contact (from left to right) with the diaphragm, abdominal parietes (epigastric region) and the under surface of the liver. The posterior surface is separated from the diaphragm, aorta, pancreas, spleen, left kidney, left adrenal gland, transverse mesocolon and colon by what is known as the lesser sac of the peritoneum (see p. 208), the so-called " stomach bed " being formed by the left kidney, the pancreas and spleen.

The blood supply comes in the right and left gastric arteries

(which run along the lesser curvature), and in other branches of the coeliac artery (hepatic and splenic).

The nerve supply is as follows. The right vagus goes to the posterior surface; the left vagus goes to the anterior surface; both these surfaces are also innervated by sympathetic branches of the coeliac plexus.

The Small Intestine.—Immediately below the stomach, the alimentary tract resumes its tube-like characteristics. The first portion is called the small intestine; when fully dissected and spread out, this measures about 20 feet. It is convoluted and ends at the ileocaecal valve of the large intestine. It is fixed to the spine by a mesentery, which is a part of the peritoneum, the serous membrane which binds together the abdominal organs (see pp. 208, 209). The actual space occupied is very small, because the tube is coiled on itself and is packed into a space in the umbilical region of the abdomen.

Divisions of the Small Intestine.—The small intestine is divided into three parts: 1. the duodenum; 2. the jejunum; 3. the ileum.

The duodenum is curved like a horse-shoe and is 10 inches long. It embraces the head of the pancreas. About 4 or 5 inches from the pyloris, there is a small elevation known as the duodenal papilla or ampulla of Vater; into this there are the openings of the common bile duct and the pancreatic duct.

The jejunum is the portion occupying about $\frac{2}{5}$ of the remainder of the tube; its coils mark the central portion of the abdomen.

The ileum is the last $\frac{3}{5}$ of the small intestine; it lies below the level of the umbilicus and terminates just above the right groin at the ileocaecal valve.

Like the stomach, the small intestine consists of 4 coats, but the muscle coat has only 2 layers, an external one consisting of longitudinal fibres and an internal one composed of circular fibres which are thick, but which do not form complete rings. The mucous membrane lining the tube is thrown into pleat-like folds, called valvulae conniventes. All over the surface of the membrane is a fine velvet pile formed by the villi which are described in full later on.

The Large Intestine.—The large intestine is so called because of its greater width; in length it is about 6 feet only. It begins at the ileocaecal valve and ends at the anus. The change from the small to the large intestine is very sudden. The small intestine opens into the caecum, which is the first part of the large intestine, and lies just above the brim of the pelvis on the right side. A double fold of the mucous membrane forms the iliocaecal valve, which apparently controls the exit of the small intestine and prevents back-flow from the wide caecum.

It is possible to divide the large intestine into 5 portions. The

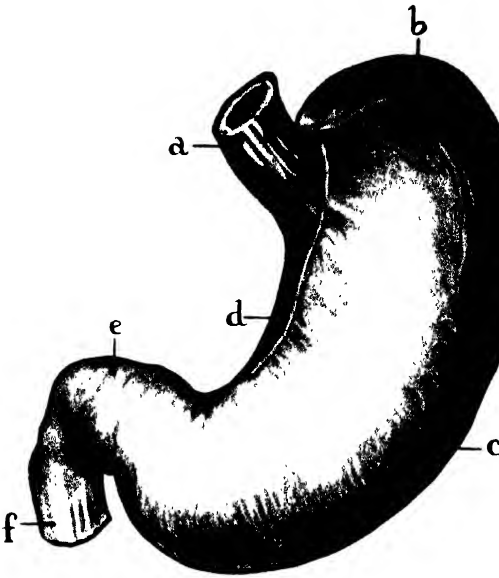


FIG. 130.—THE STOMACH. EXTERNAL ASPECT.

a, Oesophagus. *b*, Fundus. *c*, Greater curvature. *d*, Lesser curvature. *e*, Pylorus. *f*, Duodenum.

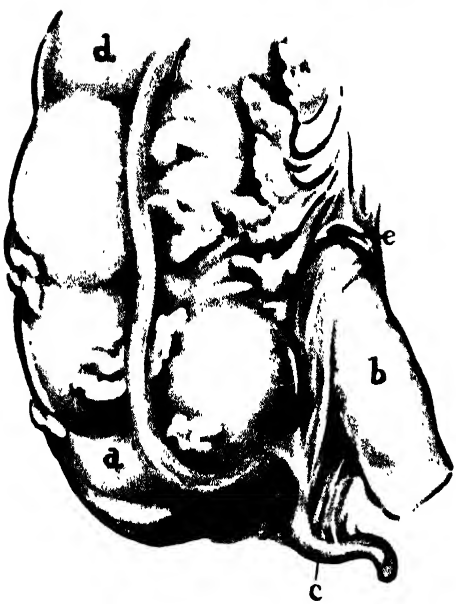


FIG. 131. THE CAECUM AND THE VERMIFORM APPENDIX.

a, Caecum. *b*, Terminal part of ileum. *c*, Vermiform appendix or process. *d*, Ascending colon. *e*, Superior ileocaecal fossa.

caecum is a small pouch, roughly 3 inches broad and 2½ inches long, closed and rounded off below, and opening above into the next portion of the large intestine, which is called the ascending colon. Just below the liver the tube bends at the hepatic or right flexure and travels across the abdomen as the transverse colon, sagging slightly in the middle. At the spleen it takes another turn, the splenic or left flexure, and descends as the descending colon, which becomes the pelvic colon, or sigmoid flexure. After that the large intestine enters the true pelvis and becomes the rectum. It will be noted that the large intestine forms a great arch occupying the whole width of the abdomen, with the coils of the small intestine within the arch.

The muscular coats are somewhat different from those of the small intestines. The outer longitudinal coat is represented by long external bands, which pass along the axis of the tube and cause a sacculation; thus the large intestine seems to be made up of a series of pouches.

The mucous membrane is smooth and does not have villi.

The mesentery is known as the mesocolon, and fixes the various portions to the posterior abdominal wall. It is fully discussed with the peritoneum below. It should be noted that small pouches of peritoneum containing fat, the appendices epiploicae, are appended chiefly to the transverse colon.

The Vermiform Appendix.—Although a very small member of the community, this organ may be acknowledged to be the most notorious member of the abdominal family. Probably a remnant of the past, it is a worm-like outgrowth from the caecum, measuring 2-5 inches long, and provided with a blood supply and a small mesentery. Being a blind alley, the appendix is a trap for small portions of food, microbes and faeces, and therefore is easily inflamed, with dangerous results. The appendix has been called the abdominal tonsil, but very little is known of its lymphatic properties (see Fig. 131).

The Rectum and Anus.—The last 5 inches of the canal are known as the rectum, which is a depot for the waste products of the bowel prior to their evacuation through the anal canal. The latter is a very firm muscular channel, 1½ inches long, terminating in the anus. The muscles of this region are fully described on pp. 124–125. The sphincter muscles of the anus keep the orifice tightly closed and are relaxed only during the movement of the bowels.

Organs Associated with the Alimentary Canal

The Salivary Glands.—There are 3 groups of salivary glands, as shown in the illustration (Fig. 132). They all manufacture saliva, the first digestive juice.

The parotid glands are single glands, lying one on each side of the face below and in front of the ear, just above the angle of the mandible. These glands are the glands affected by mumps; they communicate with the mouth by Stenson's (parotid) duct, a canal which opens on the inside of the mouth just opposite the second upper molar tooth. The parotid glands are the largest of the group, each weighing about ⅞ oz.

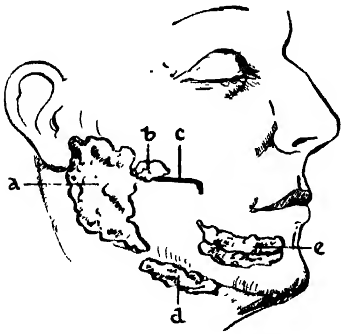


FIG. 132.—POSITION OF THE SALIVARY GLANDS.

a, Parotid gland. *b*, Socia parotidis. *c*, Parotid duct. *d*, Submandibular gland. *e*, Sublingual gland.

The submandibular glands are found below the lower jaw in front of the parotid gland. They are slightly smaller than the parotids, and open into a small papilla near the fraenum of the tongue on the floor of the mouth by a canal 2 inches long called Wharton's (submandibular) duct.

The sublingual glands are the smallest of the 3 groups, lying beneath the mucous membrane under the tongue, close to the lower jaw. They have several (sublingual) ducts, the ducts of Rivinus, and the ducts of Bartholin, varying in number from 10 to 20, and opening either into Wharton's duct or directly at the fraenum.

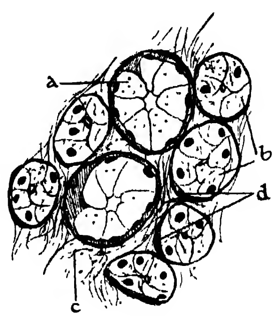


FIG. 133.—SECTION THROUGH THE SUBMANDIBULAR GLAND.

a, Mucous alveolus. *b*, Serous alveolus. *c*, Basement membrane. *d*, Demilunes of Heidenhain.

Structure of the Salivary Glands.—These glands are divided in a manner similar to that of the lungs, forming a structure like a collection of minute bunches of grapes (racemose glands). Each gland thus presents lobes and lobules bound together by areolar tissue, and shows many ramifying vessels. The capillaries are distributed over the alveoli in a way similar also to the arrangement found in the lungs. The alveoli are lined by mucous or serous glands, which collect their secretion from the blood and pour it into the ducts.

The Liver.—This is the largest gland in the body and is of supreme importance in the digestive and other systems. It

is a flabby organ, somewhat wedge-shaped, with the tip pointing towards the stomach, and it occupies the upper right-hand corner of the abdomen, lying under cover of the diaphragm and the lower ribs. Its colour and consistence are much the same as the liver of the ox or sheep. The human liver weighs about 3½ pounds and consists of 2 main lobes, right and left (Figs. 134 and 135). The upper surface forms a solid dome, in close touch with the under surface of the diaphragm; the under surface is concave and much more irregular, showing various areas in contact with the stomach, duodenum, right colonic flexure, right kidney and right adrenal gland. Five fissures can be distinguished. The posterior surface of the liver is flat, but grooved longitudinally by the inferior vena cava, and indented by the vertebral column. The front of the liver is a sharp margin, with depressions for the rounded end of the gallbladder and for the round and falciform ligaments.

The Under Surface.—The 5 fissures can be described as roughly forming the letter H. These are as follows: 1. the fissure for the ligamentum teres; 2. the fissure for the ligamentum venosum; 3. the fossa for the gallbladder; 4. the fissure for the inferior vena cava; 5. the porta hepatis, sometimes referred to as the transverse fissure (transmitting the portal vein, hepatic artery, hepatic vein, hepatic ducts, nerves and lymphatics).

The right lobe is separated from the left lobe inferiorly by the fissures 1. and 2., mentioned above, and on the upper surface by the falciform ligament. The quadrate lobe is in front of the transverse fissure, while the caudate lobe, or lobus Spigelii, is behind it. A small outgrowth from the latter is a bridge from the caudate lobe to the right lobe and is known as the caudate process.

The 5 ligaments connecting the liver to the under aspect of the diaphragm and the anterior wall of the abdomen are formed by the peritoneum, with the exception of the round ligament (ligamentum teres) which is the remnant of the umbilical vein of the foetus. The 4 peritoneal ligaments are called the suspensory or falciform ligament, the coronary ligament and the 2 lateral or triangular ligaments, all fixing the liver firmly to the diaphragm and to the abdominal wall. The round ligament runs from the umbilicus to the longitudinal fissure and so to the inferior vena cava.

The Hepato-biliary Capsule.—The hepatic artery, the hepatic (bile) duct and the portal vein are all very close together at the hilum of the liver; they are invested by a sheath called the hepato-biliary or Glisson's capsule. The hepatic veins are not invested by this capsule; they run to the fissure for the inferior vena cava.

The Vessels of the Liver and the Liver Substance.—These are best

considered together, as they are closely allied, and the understanding of one is involved in the knowledge of the other. The liver is a very vascular organ.

The unit of liver tissue is the lobule. Thousands of these are bound together by fine areolar tissue containing branches of the ducts and vessels. Each lobule may be said to be a complete gland, as it has all the properties of single glands found elsewhere. The average size of a lobule is 1 millimetre; it is irregular and polygonal but it is best regarded as pear-shaped. Its constituents are rows of hepatic cells, originally spherical, but polygonal on account of pressure all round. These cells are the active, secretory elements of the liver tissue; they may have one or two nuclei, and their protoplasm contains fatty particles, iron and glycogen, all important substances in nutrition. A hepatic cell is about $\frac{1}{1500}$ inch in diameter.

In the lobule, the grouping of the hepatic cells is such that columns are formed making a simple gland-element, this pouring out bile into primary channels or bile ducts, which eventually join with other bile ducts to form a network of hepatic ducts of minute calibre; these join to form the interlobular ducts, and so reach the bile duct in the hepato-biliary capsule. It is now clearly established that even in the cell substance there are small intracellular bile capillaries as well as vacuoles apparently acting as their source; these very minute channels probably squeeze out the infinitesimally small drop of bile contributed by the protoplasm of the hepatic cell into the bile capillaries round them.

Turning to the portal vein, which carries nourishment to the hepatic cells and therefore runs in a direction opposite to that of the bile duct, we can trace it first in the hepato-biliary capsule. Subdividing at the lobule as the interlobular vein, the portal vein invests the lobule with a network of capillaries, penetrating between the rows of cells which form the gland-element and ultimately reaching the inside of the hepatic cells by the smallest channels ending among the protoplasm. This is therefore much the same as the system adopted by the hepatic duct. The ultimate portalvein capillaries are often deficient in endothelium, so that the blood is directly in contact with the liver cells; these minute capillaries continue through the lobule and ultimately empty into a central channel of the pear-shaped mass. There is no lymph-medium, as in other glands. The central channel is called the intralobular canal, and it ends in what might be termed the stalk of the pear—a vein known as the sublobular vein—and then proceeds to join the hepatic veins and the inferior vena cava.

The hepatic artery is a simple method of nourishment of the hepato-biliary capsule, the hepatic cell substance and the con-

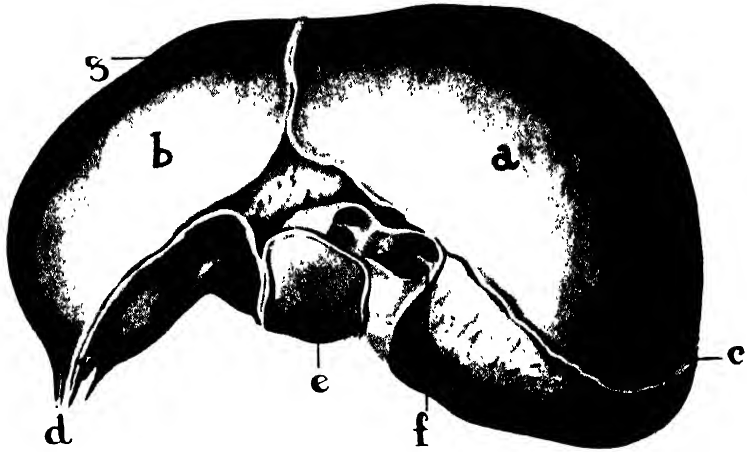


FIG. 134.—THE LIVER. SUPERIOR ASPECT.

a, Right lobe. *b*, Left lobe. *c*, Right triangular ligament. *d*, Left triangular ligament. *e*, Caudate lobe. *f*, Inferior vena cava. *g*, Attachment of falciform ligament.

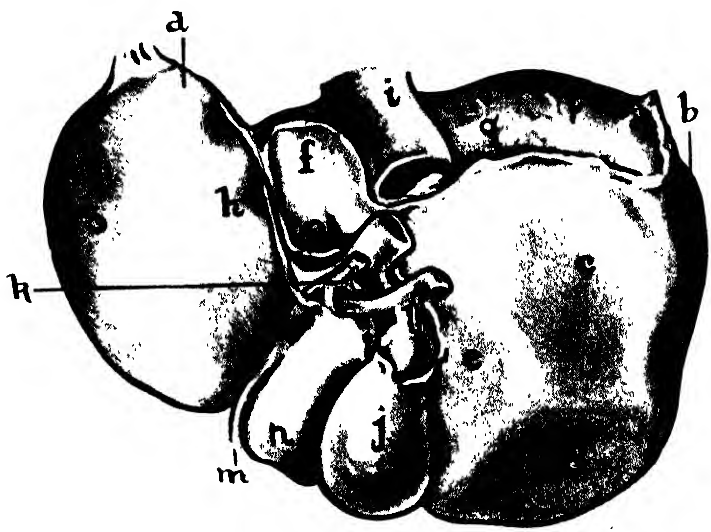


FIG. 135.—THE LIVER. INFERIOR ASPECT.

a, Left lobe. *b*, Right lobe. *c*, Renal impression. *d*, Colic impression. *e*, Duodenal impression. *f*, Caudate lobe. *g*, Gastric impression. *h*, Tuber omentale. *i*, Inferior vena cava. *j*, Gallbladder. *k*, Hepatic artery. *l*, Bile duct. *m*, Ligamentum teres hepatus. *n*, Quadrate lobe. *o*, Papillary process. *p*, Non-peritoneal surface. *q*, Adrenal impression.

nective tissue. Its blood finally reaches the intralobular vein by the portal capillaries.

The Hepatic Ducts and Gallbladder.—All the hepatic ducts from the lobules terminate in two main ducts, which, uniting at the porta hepatis, form the terminal hepatic duct. This is about 1½ inches long.

The gallbladder is a pear-shaped sac, half-membrane and half-muscle, which lies underneath the liver with the rounded end or

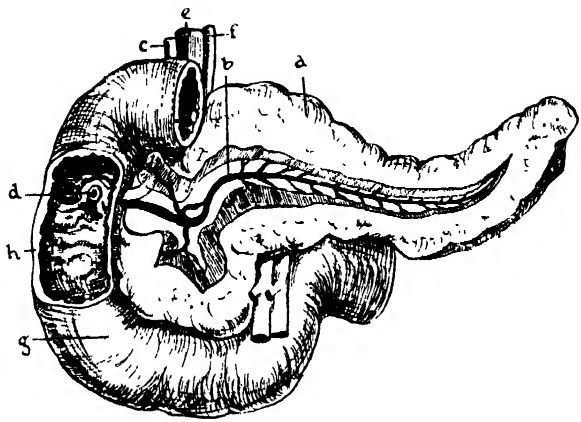


FIG. 136.—THE PANCREAS. (Cut to show duct.)

a, The pancreas. *b*, Duct. *c*, Bile duct. *d*, Orifice of bile duct and pancreatic duct. *e*, Portal vein. *f*, Hepatic artery. *g*, Duodenum. *h*, Duodenum cut.

fundus pointing forwards. It is over 3 inches long, and holds about 10 drachms of bile (Fig. 135). Following the gallbladder backwards, we come to the S-shaped neck, which is narrow, and which opens into the cystic duct, a tube 1½ inches long and having its mucous lining twisted into spiral folds. This duct joins the hepatic duct to form the common bile duct. The latter is 3 inches long, consists of peritoneal, muscular and mucous coats as in the gallbladder, and opens into the duodenum at the ampulla of the bile duct (formerly known as the ampulla of Vater or the duodenal papilla). This acts as a sort of controlling valve, opening fully after a meal. The gallbladder is the storehouse and concentration depot for the bile.

The Pancreas.—The structure of the pancreas is very like that of a salivary gland; it is compound and racemose. Measuring about 5½ inches by 1½ inches, it lies at the level of the first

lumbar vertebra, behind the stomach. It is divisible into three parts, a head, body and tail; the head is surrounded by the duodenum, while the tail is close to the spleen. It has no proper capsule, its lobules being loosely connected by areolar tissue. Its substance is like that of other glands viz. numerous closed pouches with a capillary network all round. Beginning at the tail, small ducts lead from the lobules and unite to form the main central pancreatic duct which runs along the centre of the gland. It joins the bile duct as the latter passes obliquely through the

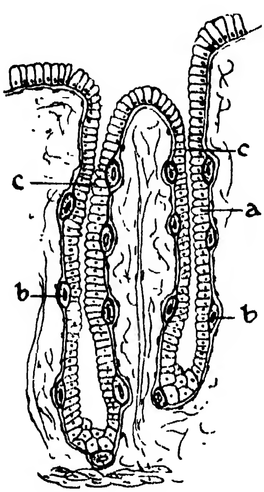


FIG. 137.—DIAGRAM OF A FUNDUS GLAND.
a, Chief cells. *b*, Oxyntic cells. *c*, Duct.

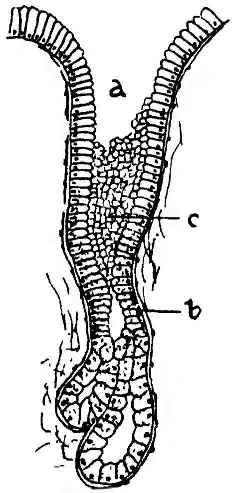


FIG. 138.—DIAGRAM OF A PYLORIC GLAND.
a, Mouth. *b*, Neck *c*, Duct.

wall of the second part of the duodenum, and then becomes the ampulla of the bile duct (see above). The bile duct and the pancreatic duct have thus a common vestibular ending. Scattered in the substance of the gland is an entirely distinct group of cells called the islets of Langerhans (interalveolar cell islets); this group actually constitutes a very important ductless gland which is fully discussed later (p. 238). The blood from the pancreas ultimately travels to the liver by the portal vein.

The Gastric and Intestinal Glands.—The lining membrane of the alimentary canal varies at different places. In certain organs, the cells are specialised into groups which act like glands, and have important influences on the food as it passes along.

Gastric Glands.—The gastric glands are 3 in number: cardiac, fundus and pyloric. These consist generally of simple tubes of variable length, lined by columnar epithelium and opening often into a duct common to two or three. They are all situated on a basement membrane. The pyloric glands are often branched and their ducts are longer than those of the fundus. The gastric juice is secreted by all these glands (Figs. 137 and 138).

Glands of the Bowel.—The villi, already mentioned, consist of fine vascular hairs, projecting from the lining of the small intestine in its whole length. It is estimated that there is a total of 4 millions. On section, they are as shown in the diagram (Fig. 139). The central vessel is called a lacteal, and there is a surrounding plexus of blood vessels, over which runs the basement membrane. The function of the villi is to absorb nourishing elements.

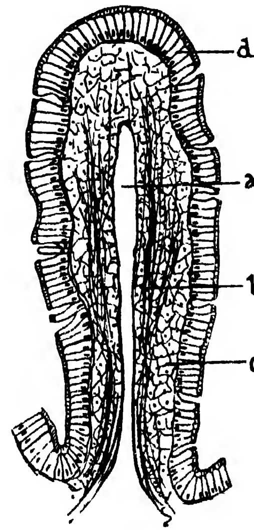


FIG. 139.—VERTICAL SECTION THROUGH A VILLUS.

a, Central lacteal. *b*, Unstriped muscular fibres. *c*, Reticular tissue. *d*, Columnar epithelium.

Four different types of glands secrete the succus entericus, which further digests the food. These are 1. the duodenal glands (Brunner's glands); 2. the intestinal glands (crypts of Lieberkühn) which open out at the bases of the villi; 3. the solitary glands—lymphoid nodules found chiefly in the ileum; and 4. the aggregated lymphatic nodules (Peyer's patches), found in the ileum and consisting of areas often extending for several inches. The last-named are especially important in typhoid fever. In structure these glands are branched and convoluted.

In the large intestine, crypts of Lieberkühn are present but there are no villi. The main secretion is that of mucus.

The Peritoneum

A double serous membrane, the peritoneum, is found in the abdomen, forming coverings for organs, filling up various spaces, functioning as visceral ligaments and acting as partitions between regions. For practical purposes it is best to consider the peritoneum as a closed bag of thin membranous material, which is laid over the abdominal contents as a covering when

the organs are set in position. If we could further imagine the layers of muscle being laid over this bag, we should have a full realization of the numerous ways in which the membrane ramifies, for a certain part of the bag adheres to the back of the abdominal muscles, and is called the parietal peritoneum, while another portion runs into the various corners between organs and sometimes forms double layers which act as suspensory ligaments for various organs. The peritoneum acts very much as a thick fluid which has been poured over a very uneven and fissured space and has been allowed to set as a fibrous apron. The two layers of the peritoneum sometimes stick together, but it should always be remembered that the sac is the basic structure, containing a greater or lesser amount of serous fluid, which acts as a lubricant. Furthermore, the attached aspect is of the nature of areolar tissue, while the inner surface is covered by endothelium, which is moist and smooth.

At one place, known as the opening into the lesser sac (foramen of Winslow), the peritoneum becomes constricted like an hour-glass, thus forming two bulging sacs, known as the greater and lesser sac respectively.

The Greater Sac.—This is situated on the upper part of the abdomen, partially covering the liver, the stomach, the greater omentum and the mesocolon.

The Lesser Sac.—This is found behind and below the liver, at the back of the stomach, above the mesocolon, forming part of the greater omentum and behind the lesser omentum which connects the liver and stomach.

The Omenta.—An omentum is a peritoneal fold connecting the stomach with some other organ. Three are described. Some anatomists include the omenta with the abdominal ligaments described below.

The Greater Omentum is simply an exaggerated pleat, which hangs down from the front of the stomach like a fatty apron, covering the intestines. It has therefore 4 layers of peritoneum.

The Gastrohepatic or Lesser Omentum separates the greater from the lesser sac; and runs from the under surface of the liver to the upper border of the stomach.

The Gastrosplenic Omentum is the connection between the stomach and spleen. It is attached to the great omentum at its lower border (see below).

The Mesenteries.—These are supporting folds of peritoneum mooring the coils of intestine to the posterior abdominal wall. They act also as the framework over which the vessels flow towards the portion of bowel they supply. All mesenteries are also well supplied with glands and lymphatic vessels. The mesentery proper is a fan-shaped fold attached to the major

portion of the small intestine. The transverse mesocolon is especially situated to support the transverse colon; it is formed by the 2 posterior layers of the greater omentum.

Ligaments of the Peritoneum.—There are about 17 folds of peritoneum which form supporting ligaments apart from the omenta. The chief are as follows.

The gastrosplenic (stomach to spleen), mentioned above;

The hepatic (4 in number, already described on p. 203);

The splenic (suspends the spleen);

The vesical (known as the 5 " false " ligaments of the bladder);

The uterine (6 in number, connecting the uterus to the bladder, rectum and sides of the pelvis).

The Pelvic Peritoneum.—In the pelvis of the male the peritoneum lies on the rectum and upper surface of the bladder, and so turns on to the back of the abdominal wall. In the female the peritoneum is pushed up, so to speak, by the top of the uterus; thus two pouches are made, one in front of the uterus called the uterovesical pouch, and one behind it, the recto-vaginal pouch (pouch of Douglas). The latter is very important in obstetrics and gynaecology, forming a deep pocket between the rectum and uterus.

Two things must be noted in conclusion.

1. The peritoneum in the female is not a closed bag on account of the fact that the uterine tubes lead into the inside of the membrane;

2. The kidneys and pancreas have no peritoneal investment.

CHAPTER 16

THE DIGESTIVE SYSTEM—FOODSTUFFS AND ACCESSORY FOOD FACTORS

FOODSTUFFS. FOOD. CLASSIFICATION OF FOODS. PROTEINS. CARBOHYDRATES. FATS. WATER. SALTS. VITAMINS. FOOD VALUES. NORMAL DIET OF MAN. CONSTITUENTS OF DAILY MEALS. ADJUNCTS TO FOOD. THE COMPOSITION OF MILK. MILK. ANALYSIS OF MILK.

BEFORE going on to the study of the physiology of digestion and absorption, it is necessary to have a clear conception of the materials used by the alimentary system. A brief outline is therefore given of the essential foodstuffs and of the normal diet of man, but the subject is treated more fully later on (see Section III, Chapter 9).

Foodstuffs

In considering the structure of the human body (p. 4), we found that each cell is made up more or less of groups of elements of a chemical nature, some 20 types being recognized; we also learned that there are 5 main compounds viz. proteins, carbohydrates, fats, salts and water. These constituents are frequently being reduced by wear and tear, by combustion and by the various demands involved in the production of warmth, movement and energy. Not only do they require replacement, but an additional supply of material is necessary for the new building schemes of the growing body. This supply is provided by the food.

Food.—The first principle which must be fully understood is that the individual cell requires its renewals in a very simple form, but that these essentials are not available in requisite amount in the elementary state required by the protoplasm. We are able to maintain, however, a supply of protein, carbohydrate, at, salts, water and the accessory food factors called vitamins, all of which provide ample amounts of the building-stones of the cells in a complex form. Subjected to the process

of refinement and breaking-up which goes on in the digestive system, these foods can be reduced to their simple constituents and thus play their part in the nourishment of the tissues when and where necessary.

Classification of Foods.—There are 2 main groups of food, the organic and the inorganic. Examples of the former are the proteins, carbohydrates and fats; of the latter, water and salts. The vitamins are best treated separately.

Protein or Albuminous Food.—This is represented by butchers' meat, mutton, pork, chicken, fish and other fleshy foods. In addition to this there are sources such as milk, cheese, eggs, bread, flour, oatmeal, peas, lentils, beans and potatoes. Generally speaking, every article of food contains a certain percentage of protein, fat and carbohydrate, but the predominant constituent is the factor which counts in the classification. Food to be of real use must have a certain minimum bulk, and even with this fundamental stipulation there is also the restriction that only a certain amount of the protein or fat or carbohydrate can be used (" digestibility ").

The proteins are complex substances in which are combined nitrogen, carbon, hydrogen, oxygen, sulphur and phosphorus, but the nitrogen is the element outstanding in the compound, so that proteins are often called nitrogenous foods. The chief function of the proteins is cell repair and new construction, and above all, stimulation of the production of heat. This last property is called the specific dynamic action. The amount of essential protein in an article of food available for use in the body depends upon the type of flesh and the methods of cooking, both of which are discussed later on (see Section III, Chapters 9 and 11).

Carbohydrates.—These include all starchy foods, potatoes, flour and various cereals and sugars. Generally speaking, they are represented by the vegetable tissues. Carbon means energy, the coal for the human furnace. Therefore a carbohydrate is the basis of the capacity for work; it supplies the power to ensure physical or mental labour. Its chief elements are carbon, hydrogen and oxygen.

Fats.—Fats are either animal or vegetable in origin. The animal fats are those of meat, cream, butter, cod liver oil and similar types of fat. The vegetable fats are found in coconut oil, palm oil and certain ground nuts; olive oil has little or no nutritive value. The constituents of fat are also carbon, hydrogen and oxygen but in different combination to those of the carbohydrates. Much potential energy is stored up in the fatty tissues of the body (liver, omentum, superficial fascia, mesentéry), and it is an important factor in the conservation of heat, as well as being an indispensable fuel.

Water.—It is well known that water is present in every tissue, in fact, it really forms the bulk of the body. Since much fluid is lost in various ways, constant replacements must be provided, therefore fluids are an integral part of our diet. Water dissolves many substances e.g. mineral salts, and it also acts as a diluting medium.

Salts.—Lime, magnesia, sodium chloride, phosphates and other salts are present in most foods. They are required for the bones and blood, but a certain minute percentage of mineral salts is found in all cells.

Vitamins.—Vitamins are also known as the accessory food factors. The chemistry of these substances is still under constant investigation, although much more is known about them than formerly. It may be assumed that they exist in very small quantity in certain foods, chiefly vegetables, and their absence leads to diseases such as scurvy, rickets and beriberi. So far, about a dozen vitamins have been differentiated—A, B_1, C, D, E, G, B_6, K_1, K_2, M, P, PP. Some of these are divided into sub-groups. For present purposes it is necessary to consider only the most important vitamins. The subject is discussed in greater detail in Section III, Chapter 9.

Vitamin A.—This is known as the anti-infective vitamin. It is essential for growth, is soluble in fat and is to be found in milk, butter, cod liver oil, halibut oil and certain vegetables (spinach, tomato, raw carrots). In the liver, the well known vegetable pigment, carotene, is acted upon so that vitamin A is produced. Deficiency of vitamin A gives rise to various diseases e.g. 1. xerophthalmia, a condition of dryness of the conjunctiva and a softness of the cornea of the eye; 2. night blindness, as a result of slow regeneration of certain purple elements in the retinal cells of the eye; 3. bacterial infections, because of lessened resistance.

Vitamin B_1.—Vitamin B_1 is soluble in water. It is the anti-neuritic vitamin, found in seeds, especially rice and wheat, and in eggs. When rice is polished and the germ destroyed, those who eat the rice become affected with beriberi, with marked inflammation of the nerves and general debility. The term, vitamin B_2 complex, is now becoming more and more of historical interest, since its constituents are now regarded as independent factors and bear distinctive letters (G, P, and so on). (For further and more comprehensive data see Section III, Chapter 9.)

Vitamin C.—Oranges, lemons, fresh vegetables and other fruits contain vitamin C. It is water soluble, and easily destroyed. Its absence causes scurvy.

Vitamin D.—This is fat soluble, and closely allied to vitamin A. Absence of it leads to rickets. It is found in cod liver oil, halibut

liver oil, tuna liver oil, herrings, egg yolk and butter, and appears to be strengthened by the action of ultra-violet rays. This vitamin is abundant in the milk of cows feeding on grass under natural conditions.

Vitamin E.—This substance, also known as tocopherol, is found generally in wheat germ, meat and leafy vegetables; it is called the anti-abortive vitamin.

Vitamin K.—Vitamin K is now known to be the anti-haemorrhagic vitamin; it occurs in various green vegetables, especially spinach and cabbage. It is necessary for the formation of prothrombin, essential for the clotting of blood.

Vitamin P.—This vitamin, found in lemon juice and Hungarian red pepper, controls capillary haemorrhage by strengthening the walls of the capillary vessel. It is referred to also as citrin or hesperidin.

Food Values.—By a system of calculation, a unit amount of any article of food can be assessed according to the amount of heat it produces in the body. Every food has different values, and a certain quantity of heat must be produced for a certain period. The index of heat in the body is called the calorie. This unit expresses the value of food in terms of its ultimate heat energy, and thus each item in the dietary can be graded. It is a simple matter to take the weight of the food for a day and apply the heat values to it, giving us a total amount of calories necessary for 24 hours. This matter is discussed fully in Section III, Chapter 9; a brief description is given here so that the student may fully appreciate the physiology of the digestion and of absorption dealt with in the next chapter.

Normal Diet of Man

It is very difficult to say exactly how much a person should take as his daily ration of food. Years of war and associated food rationing have only increased this problem. Many factors are at work, and no two individuals are the same. Circumstances which influence the total food intake are age, sex, occupation, climate, body weight, state of health, the mysterious urge called appetite and many other factors. A minimum amount of calories is essential over a given period if we are to maintain our bodies at an economic level. Usually 3,000 calories per diem is the standard of intake, but those doing hard work require more. Normal physical labour requires roughly 5 lb. of food per diem, consisting of 1 lb. of meat, 1 lb. of bread, 1 pint of milk, 2 oz. of butter, with about ¼ lb. of cereals such as rice and tapioca. About 20 oz. of fluid are required daily, but this should be

regarded as a minimum. In terms of basic materials the average daily requirement is, according to Voit:

Protein . .	120 grammes (4 oz.).
Fat . . .	100 grammes ($3\frac{1}{3}$ oz.).
Carbohydrate .	333 grammes (11 oz.).

Roughly this amounts to 3,000 calories. It must be remembered that the meat as we see it on the plate at meal times contains only a proportion of assimilable substance; for example ox flesh contains about 20 per cent of usable protein, and therefore if we have $\frac{1}{2}$ pound of meat only $\frac{1}{5}$ of its bulk comes into the reckoning, equivalent to $1\frac{3}{5}$ of an ounce, or 48 grammes, which would produce nearly 200 calories.

Constituents of Daily Meals.—Assuming that the average man has 4 meals a day (breakfast, dinner, tea and supper), the ration of protein, carbohydrate, fat, water and other items is spread over about 15 hours. All varieties of food are available, and within the limits, the amounts taken at each meal vary with the demand. Every meal consists of the basic necessities in a proportion decided upon by experience of generations. A typical dinner menu consists of soup (protein, carbohydrate, fat, salts and water), meat (protein), potatoes (carbohydrate), fat, green vegetables (carbohydrate), semolina (carbohydrate), fruit (carbohydrate and water) and so on.

Adjuncts to Food.—In certain circumstances, adjuncts are necessary to food, since they act as stimulants to digestion although they have little or no food value. Thus we have the condiments, which include mustard, pepper, curry, ginger and others of a similar nature; another class consists of the stimulants (tea, coffee, cocoa, alcohol), which by their contained drugs stimulate the tissues. Fruits and certain vegetables are popular more on account of their taste than of their nutritive properties. The armamentarium of the kitchen contains a score of "seasoning" extracts which function as brisk stimulants to the palate.

The Composition of Milk

Since milk is the first, and often the last, food of man, it may be studied as an ideal medium, containing all the essentials in one emulsified mass. It is a complete food. Eggs are also sufficient in themselves to nourish the developing chick, but they contain very little fat and sugar, the yolk being chiefly protein in character. Meat is very rich in protein (about 20 per cent), but 75 per cent is water. The common carbohydrates, flour and potatoes, chiefly consist of starch. These foods are fully dealt with at a later stage (see Section III, Chapter 9).

Milk.—The secretion of milk is the natural sequel of motherhood in all the higher animals. It is formed from the blood in the mammary glands, and is drawn off by suction at the nipples, which have a valve-like structure. Taking cow's milk as an example, we find its composition to be as follows:

Protein	3·5	per cent
Fat	3·7	„
Carbohydrate	4·9	„
Salts	0·7	„
Water	87·2	„

This is about twice as strong as human milk in proteins, of the same strength in fats, but not so sweet.

It is possible for an adult to live on milk, but the quantity required would make life uncomfortable. For children of tender years, milk is a perfect food; it is, however, somewhat deficient in iron.

Analysis of Milk.—Under the microscope, milk is seen to be made up of numerous small globules of fat of varying size floating about in a clear fluid. When milk is allowed to stand, the fat (cream) rises to the surface and leaves the sugar and protein behind—a heavier solution. The specific gravity of full milk should be about 1,030 (cow). On chemical analysis, milk is found to contain caseinogen, a protein which yields casein when coagulated by rennet. Milk also contains a small quantity of albumin—lactalbumin. The chief fat of milk is butter, which is not very much different from the fat of the adipose tissue. Small quantities of olein, palmitin and stearin are also present. The sugar of milk is lactose; when milk stands for a certain time it sours, since the micro-organisms become active and convert the lactose into lactic acid. Milk also contains calcium phosphate, magnesium phosphate and sodium chloride.

CHAPTER 17

THE DIGESTIVE SYSTEM—THE PROCESSES OF DIGESTION AND ABSORPTION

SECRETION. MASTICATION. SALIVA. DEGLUTITION. GASTRIC DIGESTION. GASTRIC JUICE. GASTRIC MOVEMENTS. DIGESTION IN THE SMALL INTESTINE. SUCCUS ENTERICUS. THE ACTION OF BILE. THE ACTION OF THE PANCREAS. THE PROCESS OF ABSORPTION. THE END PRODUCTS OF DIGESTION. HOW ABSORPTION TAKES PLACE. THE LARGE INTESTINE. THE FUNCTIONS OF THE LARGE INTESTINE. DEFAECATION.

DIGESTION is a process of breaking up of the food. The work begins as soon as the food reaches the mouth, and as the mass slowly travels along the alimentary canal it is influenced by various secretions, which are poured out from glands at successive stages, until the essential nourishing materials are extracted. Absorption then takes place and the waste products are rejected.

Secretion.—The structure of a typical secreting cell may be studied by looking at Fig. 133, p. 202, or Fig. 137, p. 206, which show the composition of a salivary gland and of a stomach gland. The active cells of the gland are full of granules, which are the parents of the fluid to be secreted. They are separated from the capillaries by a minute quantity of lymph. The main functions of a secreting gland are the selection of certain dissolved substances from the blood in the adjacent capillaries and the addition to it of further matter from the gland cells. The latter is very important, as it explains why the constituents of a secretion like bile or hydrochloric acid may be very powerful, and the result of a complex chemical and physical action. Gland cells are very active at all times; even when the gland is (so-called) " at rest " the individual cells are manufacturing a reserve of granules. No definite knowledge is available about the pumping power of the cell. No doubt there is a strong osmotic action, which depends on peculiar properties of the cell membrane, but it is a very obscure subject, and we must take much for granted in accepting the theories which explain how powerful juices are compounded in these small simple tubes and delivered to the food as it passes along.

Mastication.—When a small bolus of food is put into the mouth it is grasped by the incisors, and by the action of the upper row of teeth on the lower the material is chopped into small pieces. These are then rolled about in the mouth, being thoroughly mixed with saliva in the process; finally the food is minced by the molars. The pressure of the tongue and of the cheek muscles also crushes the soft portions of food against the jaws and hard palate. The longer the food is chewed, the more is it mixed with saliva.

Saliva.—The 3 salivary glands begin to act before the food is put into the mouth, stimulated as they are by hunger, thirst and the savoury smell of the food. The process is initiated by nerves, the submaxillary and sublingual glands being governed by the chorda tympani and the parotid by the auriculotemporal nerve. These, plus the taste buds of the tongue, stimulate the "watering" of the mouth. Anxiety, fear and other emotional factors may cause a great diminution in the flow of saliva.

Saliva is a product of all 3 glands, each contributing its portion to form a composite fluid which is somewhat slimy and not quite clear. Occasionally little nodules of mucin are present. Saliva is alkaline, is slightly heavier than water and contains only ½ per cent of solids. These consist of certain salts, mucin, protein and a fermenting agent (enzyme) for starch, known as ptyalin. Ptyalin acts on the substance of the starch granules in the food and reduces them eventually to malt sugar; a proof of this is furnished when we experience the sweet taste after putting a piece of potato in the mouth. The saliva also acts in a physical way, lubricating the mass of food and the mucous membrane of the mouth and so permitting ease in swallowing and freedom in talking. Recent work has proved that salivary digestion may go on in the stomach for a much longer time than formerly believed; especially is this so when the acid secretion of the stomach is scanty.

Deglutition.—This is the technical name for swallowing: the act of transferring the food from the mouth to the stomach; 3 stages are distinguished.

1. *Preparation of the Bolus.*—The insalivated mass of food is pressed by the muscles of the back of the tongue against the arch of the palate and then reaches the entrance of the pharynx, at the anterior pillars of the fauces.

2. *Transfer to Oesophagus.*—This is a complex but well managed performance. As the mass passes through the pharynx, the soft palate rises to close the posterior nares while the anterior pillars of the arch contract. At the same time the retraction of the tongue pulls up the larynx and pharynx, while the epiglottis is closed. Thus we are certain of having closed doors guarding

the larynx and nose. Meanwhile, there is a general contraction of the pharynx, so that the roof is an inclined plane, down which the bolus easily slips. Meanwhile the pharynx "accepts" the food, and by successive contraction of its 3 muscles passes the bolus into the oesophagus.

3. *Passage through the Oesophagus.*—As soon as food reaches the gullet, there is a reflex stimulation of the muscles, so that those in front are flaccid and those behind the bolus contract firmly. This is a common type of action known as peristalsis. It is a movement similar to that seen in the crawling of worms.

The first part of swallowing is voluntary, but it rarely comes into our active thoughts. The last two parts are involuntary.

Gastric Digestion.—Before the mechanical movements of the stomach are dealt with, a brief study must be made of the gastric juices manufactured by the simple glands of the stomach already described (p. 206). These juices are poured out as required, and their flow is prompted by the stimulation of the vagus nerve; the sympathetic system also takes part. There is no doubt that psychical influences are strong, as instance the various nervous sicknesses and the frequent occurrence of indigestion in highly strung individuals. Another activity of secretion depends entirely on mechanical reflexes set up because the chemicals of the food directly stimulate the glands in the stomach wall.

Gastric Juice.—An average sample of stomach secretion has the following composition:

Water .	99	per cent	
Ferments .	0·3	,,	(pepsin, rennin, lipase).
Acids .	0·5	,,	(mainly hydrochloric acid; a small amount of lactic acid).
Salts, etc. .	0·2	,,	(chlorides and phosphates).

The hydrochloric acid is variable, and may exist free or combined as chlorides, but it is in sufficient quantity to make all the food acid, and to act as an antiseptic agent to the numerous microbes taken with the food. Mention has been made above of the action of saliva in the stomach. Normally hydrochloric acid tends to inhibit the activity of ptyalin in the stomach, since this ferment is capable of full effect only in an alkaline medium. Hydrochloric acid also splits up cane sugar into glucose and fructose, slightly affects fats and curdles milk. The most important action, however, is on the meaty or protein types of food. Hydrochloric acid combined with the ferment pepsin changes protein into peptones. One of the wonders of Nature is that the stomach wall is especially protected and is not digested by the gastric juice.

Although the stomach is essentially one of the important organs connected with the digestion of food it has been credited within the last few years with another vital function—the production of haemopoietin (the blood-forming or anti-anaemic factor). There is contained in the gastric juice a ferment known as the intrinsic factor of Castle, which is capable of acting on certain foodstuffs; these have in their substance a factor, the exact composition of which is not known. For this reason it has been termed the extrinsic factor. The two factors acting on one another produce the substance called haemopoietin (see p. 147); which is essential for the proper development of the red cells in the bone marrow.

Gastric Movements.—Of the various methods employed by investigators to discover the true nature of gastric movement, the x-ray method is the most fundamental; indeed, x-ray evidence has made an alteration in many long-established beliefs. It is clear that very little movement goes on at the fundus of the stomach, but a great deal at the pyloric region, which has been called the "pyloric mill," because peristaltic waves may occur there at the rate of 3 per minute. The food is thus thoroughly mixed with gastric juice and formed into a semi-fluid mass, ready for digestion in the small intestine, and known as chyme. To a certain extent the work of the stomach is preparatory in type. During a meal we may term the action the filling of a bag, but as soon as the lowest portion of food is treated, about ½ ounce of the fluid passes into the duodenum, and this goes on regularly until the stomach is empty, which may not occur until the lapse of 3–6 hours. The apparent reason for this is that the alkaline juices of the small intestine can deal with only a small quantity of acid chyme at a time, and therefore the pyloric sphincter is relaxed only when plenty of alkali is available. Each instalment is therefore passed through a pyloric valve functioning as a clearing house.

Digestion in the Small Intestine.—We must now imagine the partially digested fluid passing slowly in sections through the small intestine. Peristaltic movements are steadily going on, and in addition there is a certain amount of to-and-fro action of the tube, which ensures further mixing of the intestinal contents. A third property, segmentation, is peculiar to the small intestine; the circular muscles contract rhythmically, thus delaying small batches of food for better digestion and absorption. In this way the intestinal contents are propelled at an even rate along the bowel.

Succus Entericus.—The glands in the walls of the intestine pour out an intestinal secretion called the succus entericus, which acts on the alkaline contents to reduce the constituents to a simpler composition. Apart from the fact that it contains much mucin,

and thus is an important lubricant, the succus entericus contains several ferments, 5 of which are prominent:

1. Enterokinase .	Assists the pancreas, described below;
2. Erepsin . .	This further reduces the peptones into amino acids, which are the simplest proteins;
3. Maltase . .	Changes maltose into glucose;
4. Lactase . .	Converts lactose into glucose;
5. Invertase .	Splits up cane sugar.

The Action of Bile.—One of the main functions of the liver is the secretion of bile, which is poured out from the common bile duct at the duodenal papilla. The gallbladder is a means of storage until the bile is required after a meal. Bile is a greenish-yellow fluid, alkaline in reaction and consisting of over 85 per cent of water. The remainder is composed of very powerful substances in solution, including the bile salts, the bile pigments (derived from haemoglobin but iron-free, and known as bilirubin and bilverdin) and cholesterol. The bile pigments are converted into stercobilin by various digestive juices and bacteria, and give the typical coloration to the stools. Six functions are performed by bile as follows.

1. It further reduces the proteins.
2. It helps the pancreas to digest fats, acting as a co-ferment with lipase (see below).
3. It helps the pancreas to split up carbohydrates.
4. It aids absorption.
5. It stimulates peristalsis and acts as an aperient.
6. It is antiseptic.

The Action of the Pancreas.—Pancreatic juice is a rather syrupy type of fluid, poured into the duodenum at the duodenal papilla. This, the external secretion of the pancreas, is strongly alkaline, containing only 3 per cent of solids. These solids are sodium chloride, sodium carbonate and various other salts. The 3 digestive ferments are described below.

1. *Trypsin.*—This acts in a peculiar way. Let us assume that the duodenal contents have been thoroughly mixed with pancreatic juice. Nothing happens to the proteins until the substance, enterokinase, combining with a parent substance, trypsinogen, produces trypsin, a reducing agent much more powerful than pepsin.

2. *Amylase.*—This is a ferment very like ptyalin, but stronger in effect, since it has the power of dissolving the cellulose of starch granules and therefore can break up raw vegetables.

3. *Lipase.*—The action of this ferment is subsidiary to the bile. It forms fatty acids and glycerine from the fats.

Pancreatic juice is a very concentrated digestive, universal in its action. The supply reaches its peak at about 3 hours after a meal; it is stimulated by the nerves, by the presence of any acid in the duodenum and by secretin, derived from the intestinal epithelium.

Since there is no real digestion in the large intestine, we can conveniently leave the consideration of the last part of the alimentary canal to the end of the chapter, and meanwhile retrace our steps to learn how the nourishing elements of the food are absorbed into the blood for distribution to the tissues.

The Process of Absorption

In its entire length, the alimentary canal is lined by mucous membrane, specialized at areas by digestive juice manufactories, and by absorptive systems. Any absorption in the stomach or large intestine is negligible, and for all practical purposes the only area we need consider is that in which the villi are found viz. the small intestine. The structure of the absorptive glands has already been dealt with (p. 207) and all that remains to be studied is the physiology of absorption.

The End Products of Digestion.—By the time the action of all the digestive juices has been completed, the 3 main types of food have been reduced to liquid solutions as follows.

(1) The Proteins are in fine solution as amino acids. This is the result of a process called hydrolysis. An amino acid is a building stone of protoplasm.

(2) The Carbohydrates are present in the form of glucose, and to a very small extent, fructose and galactose. The solution passes easily into the blood.

(3) The Fats are represented by fatty acids, glycerol and a minute amount of liquid soap.

How Absorption Takes Place.—As the 3 mixed solutions pass slowly across the velvety pile of the intestinal carpet, the villi become very active. Undoubtedly there is more than simple diffusion going on; the cells have some special vital power whereby they have a selective action on the products required for the tissues.

There are 2 main routes through the villus. First the proteins and the carbohydrates are taken up by the numerous capillaries surrounding the villi and transferred via the veins to the portal vein and thus to the liver. Secondly the fats are claimed by the lymphatic system, the elements passing into the lacteals, and so to the thoracic duct. After a meal the mesenteric lacteals are found to be full of milky chyle, an emulsion formed by the re-formed droplets. Only 60 per cent of the chyle can be

accounted for in the thoracic duct; the remaining 40 per cent is probably taken up by the blood.

The Large Intestine

It takes about 5 hours for the intestinal contents to reach the ileocaecal valve. When the caecum fills up, it contains a jelly-like liquid, coloured by bile salts, with strands here and there of the stringy cellulose from vegetables ("roughage"), flakes from the lining of the bowel, dead bacteria and mucin. Movements in the large intestine are very slow; it may take 14–20 hours to pass the contents from the ileocaecal valve to the rectum. A certain number of contraction waves pass slowly along, set up by the more active peristalsis of the ileum.

The Functions of the Large Intestine.—1. The slow progress allows the maximum absorption of water, for which the wide lumen of the bowel is so aptly designed. In addition, antiperistalsis may cause regurgitation of the fluid, so that the "drying period" is increased. The net result of this is that the intestinal contents (or faeces) are solid when they reach the sigmoid flexure. About 400 cubic centimetres of water are taken up by the large intestine every day.

2. The large intestine also secretes a quantity of mucin, which acts as a lubricant.

3. Excretion of certain salts occurs, including iron, calcium and magnesium phosphate. The drug mercury is notably excreted by the large bowel.

4. A great amount of vigorous bacterial action and decomposition goes on, with the production of powerfully smelling substances such as indole, skatole and phenol.

Defaecation.—The passage of the bowel motion is perhaps the most important event of a patient's day, and all nurses are expected to be fully acquainted with the physiology of defaecation. A normal stool varies a great deal, but generally speaking, it should be ample, coloured brown with stercobilin and semi-solid, although it contains 65 per cent of water. The act of defaecation is generally timed to occur after breakfast, but this need not be regarded as essential. The peristaltic wave set up by food in the stomach travels all the way to the sigmoid flexure, which discharges its contents into the rectum, giving the desire for emptying the lower bowel. When the act commences, the sphincters relax and intra-abdominal pressure, plus contraction of the muscles of the rectum, completes the process.

CHAPTER 18

METABOLISM

THE FATE OF THE FOODSTUFFS. THE IMPORTANCE OF THE LIVER. PROTEIN METABOLISM. FAT METABOLISM. GLUCOSE METABOLISM. HEAT AND ENERGY OUTPUT. FEVER AND CLIMATE. CONCLUSIONS.

ACTIVE life is demonstrated by the production of energy. This may take several forms, the chief of which are heat energy and mechanical energy, as already mentioned at the beginning of this work.

The word, metabolism, is used to denote the chemical and physical processes going on in the tissues to produce new protoplasm and to maintain the existing fabric. Metabolism is thus intimately associated with the absorption of the end products of digestion, but the various ways in which energy can be made available for the organism can conveniently be studied also at this point.

The Fate of the Foodstuffs

Assuming that the proteins and carbohydrates are in the portal vein, and the fats in the thoracic duct, what happens to them, and how are the tissues responsive to them? These and many other very difficult questions must be answered, and in the space at our disposal we can deal only with the most elementary factors.

The Importance of the Liver.—In addition to the production of bile, the liver has other very important functions. Taking the disposal of the amino acids first, we know that the blood must be fully charged with these bodies in the portal capillaries. The distribution to the cells is a simple matter; the muscles need replacements on account of work-loss, the glands must always be repaired and their secretions provided for; a growing child requires much protein in all his cells, and so on. The surplus amino acids are dealt with by the liver cells, which, as we already know, are especially suited for carrying out rapid absorption. The liver is really a great clearing house for the whole body. The excess proteins are transformed by a process called deaminization in the lobules into urea, which is later removed by the kidneys.

The liver also deals with the fats. A certain amount of the absorbed fat can be stored in the various fat depots of the body, but a considerable quantity remains over, and it is of use to the tissues. A process of " desaturation " goes on in the liver, resulting in oxidation and the final production of water and carbonic acid gas, with provision of much energy.

Of great importance is the glycogenic function of the liver, a system of conservation of sugar in a temporary store. The tissues have ever varying requirements of glucose. Immediately after each meal there begins an accumulation of glucose in the portal vein, so that the liver is filled up with it. Apparently the only method of storage is one of temporarily converting the glucose to glycogen, and this is done, the glycogen being again transformed when the tissues take it up as glucose for their use. The pancreas assists in this operation, providing the secretion, insulin, which by its action controls the mechanism of this important carbohydrate exchange. Carbohydrates can also be converted into fats by the liver; the process is somewhat obscure.

Other functions of the liver are the formation of uric acid; the manufacture of heparin, which prevents clotting of the blood; the production of vitamins, antitoxins, antiseptics; and the manufacture of blood in the embryo. In addition to this, the liver has ample accommodation for the storage of blood and may act as a blood-valve on occasions; so much activity goes on in the gland that the blood leaving it is always warmer than normal.

Material Metabolism

Protein Metabolism.—So many grammes of amino acid are used directly by the tissues, and so many surplus grammes are plit up by the liver into various substances such as uric acid and urea. The suprarenal, thyroid, reproductive, mucous and mammary glands are supplied with amino acid for their secretions. From all the activities in process, 2 distinct types of metabolism are described: 1. exogenous metabolism resulting from the changes in the food protein, and 2. endogenous metabolism, depending upon the changes in the body protein. The great index of protein metabolism is the urine. An estimation of the nitrogen of the urine gives valuable information of the changes going on, and of the " metabolic level " of the tissues.

Fat Metabolism.—The fats are taken up by the tissues in part as lipoids such as lecithin. As mentioned above, a certain proportion of fat is transformed by desaturation in the liver into energy, while a small percentage may be converted into glycogen. Fat is lost or increased according to the demands made on it by the individual, but in a normal person fat is stationary in its

depots. There it functions as a reserve of energy, of vitamins and of heat.

Glucose Metabolism.—The amount of sugar in the blood (blood sugar) is a constant. If there is any abnormal rise, the pancreas comes to the rescue with its insulin as a controlling factor, tying up the glycogen until the blood sugar falls to normal level.

Energy Metabolism

Heat and Energy Output.—The energy produced in a given time can be calculated by various types of calorimeters, which record the amount of heat generated. The unit used is the calorie, which represents the amount of heat required to raise one gramme of water from 15° C. to 16° C., but in metabolism problems the unit is the large calorie, which is one thousand times greater than the standard calorie. As a general rule, the total energy amount consists of roughly ¼ work energy and ¾ heat energy, conditions of activity being normal labour. Food is invariably proved to be the stimulating factor in the production of increased energy; the energy of a person at rest decreases if food is reduced. This factor is known as the specific dynamic action of food; it accounts for about 20 per cent of the total number of calories. The heat value of foods is calculated by using an apparatus called the bomb calorimeter, which completely incinerates the food placed in it and registers the temperature. Proteins give out 4 calories per gramme, carbohydrates 4 and fats 9. The amount of daily energy produced as work and heat is on a parallel with the amount of food taken. Thus grammes of food ingested are made the basis of most diet formulae.

Body Heat.—The skin, which is dealt with fully later (p. 234), is always in action as a great cooler of the body. We have therefore the constant task before us of maintaining the body at the normal temperature of 37° C. or 98·4° F. To check these temperatures, we use the familiar clinical thermometer, which records by a column of mercury the temperature of the area in which it is placed—axilla, groin, mouth or rectum. Temperature rises 5° or 6° F. during severe muscular exercise, but quickly falls again. However cold the atmosphere may be, the temperature rarely drops more than a point below normal level. Deaths from excess of heat or from cold in warm-blooded animals (e.g. human beings) are the result of overwhelming conditions, causing the regulating mechanism to break down. Heat production is governed by the nerves supplying the glands and muscles, and varies according to the state of activity of the person involved. Muscular tone also accounts for the standard of heat produced.

The bracing effect of cold weather is the result of increased tone in the muscles. Shivering is an attempt of supreme kind by the nerves to add to the heat by increasing tone to the maximum. Certain ductless gland extracts increase the heat of the body. Heat on the skin is governed in various ways. For instance, we may be warmed by hot currents of air, cooled by cold air; a hot water bottle brings heat to our skin and so warms the blood, but sitting on a slab of cold stone has the opposite effect; the evaporation of the sweat causes a cooling of the skin. Normally about 80 per cent of the heat loss is through the skin, 17 per cent by the breath and 3 per cent by the urine and faeces. The heat-regulating centre is not definitely localized in the brain; it is probably at the tuber cinereum (see p. 250). It acts by causing flushing of the skin and occurrence of perspiration when the temperature of the air is high. At the same time the muscles lose tone—the person is said to be relaxed. When cold conditions prevail, the vessels under the skin are constricted and muscle tone is increased, partly by glandular action. We put on extra clothes, eat more and work more, in an endeavour to provide the extra calories required.

Fever and Climate.—Fever is a rise of body temperature generally due to activities of millions of microbes. The symptoms of fever are easily understood when we know the meaning of the heat-producing factors at work. The shivering, thirst, high temperature and dryness of the skin are all evidences of disturbance of the heat-regulating mechanism.

Four distinct types of climate are recognized. The climate may be 1. cold, dry and bracing; 2. cold and moist—a very disagreeable type; 3. hot and dry, in which there is comparative comfort if plenty of water is drunk; 4. hot and moist, in which there is profuse sweating, but on account of the humidity of the air evaporation does not occur. The last type is the worst, being common in New York during heat waves, and the cause of unhealthy conditions.

Conclusions.—To summarize our knowledge of metabolism, we may trace the process backwards. Heat and work are closely associated. Both are the result of the fuel brought to the tissues by the amino acids, fats and glucose of the blood, which in turn are supplied from the villi of the small intestine. The oxygen necessary for the combustion of the basic elements of the food is received at the lungs. How the fire burns we really do not know. We only know the results of its burning—the production of carbonic acid gas, water and the energy of heat and of muscular movement, which both denote the vital process of life.

CHAPTER 19

THE EXCRETORY SYSTEM—KIDNEYS AND BLADDER

ANATOMY OF THE KIDNEYS AND BLADDER. THE KIDNEYS. INTERNAL ANATOMY. THE CORTEX. THE MEDULLA. RELATIONS OF THE KIDNEYS. THE KIDNEYS UNDER THE MICROSCOPE. THE URINIFEROUS TUBULE. THE BLOOD SUPPLY. KIDNEY CELLS. THE URETER. THE BLADDER. HISTOLOGY OF THE BLADDER. PHYSIOLOGY OF THE KIDNEYS AND BLADDER. HOW THE URINE IS MADE. HOW URINE IS COLLECTED. MICTURITION. THE URINE. NORMAL URINE. CONSTITUENTS OF URINE.

THERE are 3 ways by which the waste products of the body can leave—the renal way, represented by the kidneys and bladder; the epidermal way, represented by the skin; and the alimentary way, represented by the bowel. The last has already been discussed (p. 222).

Anatomy of the Kidneys and Bladder

The urinary system is composed of 2 bean-shaped glands, the kidneys, situated on either side of the spine on the back of the upper part of the abdominal wall; 2 ducts, the ureters, leading from them; a single central bladder, lying behind the pubis; and an outlet canal called the urethra.

The Kidneys.—Each kidney is about 4½ inches long, 2 inches wide and 1 inch thick, the weight being roughly 4½ ounces. It lies high up on the posterior abdominal wall, close to the diaphragm and behind the peritoneum. Its convex border is lateral; the concave border, or hilum, looks medially and gives rise to the ureter. The right kidney is slightly lower than the left, as it is pushed down by the liver (Fig. 140), but the normal kidney area may be said to extend from the last dorsal vertebra to the first lumbar vertebra. Each kidney is surrounded by a considerable amount of loose tissue, generally laden with fat; to this tissue the term, fatty (or adipose) capsule, is applied. The kidney is not a solid body; it contains a cavity known as the renal

sinus, the opening into which, termed the hilum, is situated on the anteromedial part of the organ. The vessels enter and leave at the hilum.

Forming a sort of cap to the kidney is a small, pyramidal gland called the adrenal gland, or suprarenal body. This is one of the ductless glands and is described later (p. 240).

Internal Anatomy.—When we divide a kidney longitudinally, the picture presented is as that shown in Fig. 141. From without inwards, there is a fine covering membrane of fibrous tissue—the

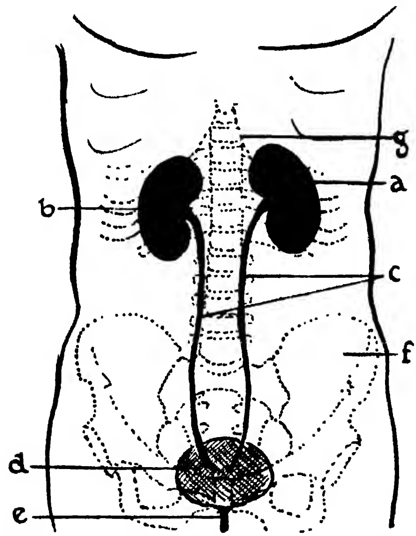


FIG. 140.—PLAN OF THE URINARY SYSTEM.
a, Left kidney. *b*, Right kidney. *c*, Ureters. *d*, Bladder. *e*, Urethra. *f*, Outline of pelvis. *g*, Lower border of sixth rib.

capsule, then the solid substance, divided into 2 distinct regions (cortex and medulla) and finally there is the funnel-shaped pelvis of the kidney narrowing to form the ureter.

The Cortex.—The tissue here is brownish-red normally, and appears to spread irregularly into the medullary area.

The Medulla.—Apparently originating in the cortex, about 15 pyramidal-shaped, pale purple masses of tissue are seen, forming the features of the next layer. These are called the pyramids of the kidney; their apices point towards the pelvis, and at each little peak, or papilla, there open a variable number of small tubes, which can be traced backwards. There are recesses in the pelvis of the kidney for these papillae; they are known as calyces.

Relations of the Kidneys.—The following table shows the relations of each kidney.

RELATIONS OF THE KIDNEYS

	Right Kidney.	*Left Kidney.*
Anterior surface	Right lobe of liver 2nd portion of duodenum	Fundus of stomach Spleen Tail of pancreas Descending colon Jejunum
Upper pole	R. adrenal gland	L. adrenal gland
Lower pole	Hepatic flexure of colon	Splenic flexure of colon
Posterior surface	Diaphragm (separating it from pleura) Quadratus lumborum muscle Psoas muscle Lumbar fascia	Part of diaphragm Psoas muscle
Medial border	R. ureter Inferior vena cava	Aorta L. ureter

The Kidneys under the Microscope.—Owing to the peculiar contour of the internal structures, it is not difficult to recognize kidney tissue under the microscope. If we trace a tubule from the papule backwards we should find that it is the termination of a most intricate and most highly developed system of filtration.

The Uriniferous Tubule.—The filter begins with the Malpighian body, now generally referred to as the renal corpuscle. This, as illustrated in the diagram (Fig. 142), consists of 2 parts. The first part is the glomerulus, consisting of a ball of capillaries, very much twisted and intertwined so as to pack the maximum amount of tube into the minimum area. A vessel enters and leaves this

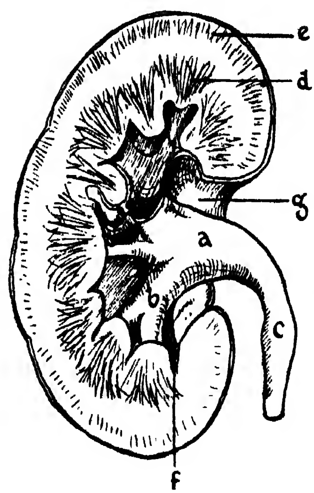


FIG. 141.—DIAGRAM SHOWING A VERTICAL SECTION THROUGH A KIDNEY.

a, Pelvis. *b*, Calyx major. *c*, Ureter. *d*, Medullary substance. *e*, Cortical substance. *f*, Renal sinus. *g*, Hilum.

mass. The second part is known as Bowman's capsule; it is the beginning of a tubule which literally embraces the glomerulus like a hood, so that the capillary mass is surrounded by kidney tubule cells. We may take it that as a general rule the cortex is the Malpighian area, while the pyramids are the collecting-tube area. Following a single tubule from the glomerulus, we find that the cortex is also a zone containing numerous tubules, all of which follow a definite pattern. When the capsule of Bowman gives place to the first convoluted tubule, it narrows considerably, and becomes very much twisted and convoluted; the next stage is the formation of a U-tube known as Henlé's loop, this dipping into the base of the medullary mass. Subsequently the tubule again becomes convoluted (the second convoluted tubule), and it opens with others into the collecting tube and so to the papilla in the terminal duct of Bellini.

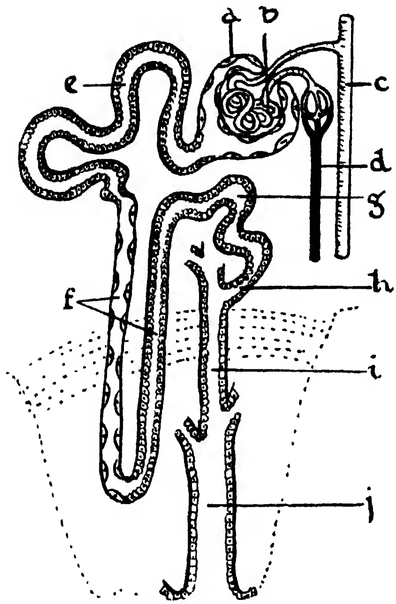


FIG. 142.—PLAN OF A RENAL TUBULE.
a, Bowman's capsule. *b*, Glomerulus. *c*, Artery. *d*, Vein. *e*, 1st convoluted tubule. *f*, Henlé's loop. *g*, 2nd convoluted tubule. *h*, Junctional tube. *i*, Collecting tube. *j*, Duct of Bellini.

The Blood Supply.—After the renal artery reaches the kidney, it subdivides until it forms a glomerulus. The efferent portion then forms a network of smaller capillaries round the kidney tubules. Having collected together again, these venules join up to form the renal vein, which in turn reaches the inferior vena cava. This double capillary service is a feature of the kidney, and is known as the Renal Portal System.

Kidney Cells.—Whereas the cells lining Bowman's capsule are flat and squamous in type, those in the tubules are columnar or cubical, with rod-like rows of granules. The U-shaped portion is peculiar in that in the descending limb the cells are flattened, whereas in the ascending limb they are cubical (Fig. 142).

The Ureter.—The calyces collectively form the pelvis of the

kidney, and the latter narrows to a point from which the ureter begins. The width of the ureter is generally agreed to be that of a goose-quill, but naturally there are variations. The usual length is 17 inches. The ureters run down to the bladder, bending slightly towards the spine in their descent. They enter the bladder at the rear portion of its floor, described below. In structure, the ureter consists of 3 coats: the outer thick and fibrous, and continuous with the capsule of the kidney; the middle muscular; the inner mucous and covered with epithelium.

The Bladder.—Various descriptions are applied to the shape of this organ, which belongs entirely to the pelvis, surrounded and well protected by bone. When full, the bladder is globular, when empty it is roughly pear-shaped or pyramidal. Its base is fixed, but its upper part rises above the brim of the pelvis when the bladder fills with urine. In front is the symphysis pubis; behind, the rectum in the male and the vagina in the female. The base, or neck, of the bladder is called the trigone, at the angles of which are the orifices of the two ureters and the beginning of the urethra.

Histology of the Bladder.—Four coats are distinguished in the bladder. The outer is derived from the peritoneum and is serous; the second consists of muscle tissue which forms a sphincter at the outlet of the bladder; underneath this coat is a submucous layer of areolar tissue; lastly the mucous coat is thin, smooth and pink, consisting of transitional epithelium. The lining membrane of the bladder becomes thrown into folds when the organ is empty, but its great function is that of easy expansion. The urethra varies in the male and female; both are described separately in the chapter dealing with the Reproductive System (pp. 287 and 291).

Physiology of the Kidneys and Bladder

The main function of the kidney is that of keeping the blood plasma in its normal physical and chemical state. The kidney is an organ of marvellous sensitivity and selectivity. It adjusts the blood pressure, keeps the salts at a standard concentration, excretes the normal fluid wastage of metabolism and digestion and gets rid of any poisonous matter from the blood. It has therefore a filter action and a secreting action, made perfect by the efficiency of its cells. This double power is very important in the maintenance of the purity of the tissues. Not only are the end products of protein, carbohydrate and fat metabolism discharged in solution, but if there is any excess (e.g. sugar) or any harmful matter, such as microbes or mineral poisons, the adjusting mechanism ensures speedy evacuation. The kidney also maintains the renal threshold. This may be explained by saying that

the blood of a person who has not had food of any kind for several hours contains about ·09–·12 milligrams per cent of glucose. When a meal rich in starchy and sugary food has been taken, the blood may show ·15 per cent of glucose. An amount greater than this generally allows a surplus to appear in the urine. It is generally accepted that ·17 per cent of glucose in the blood is the danger signal, or renal threshold, i.e. the kidney cannot shut its doors to glucose in blood concentrations above this level. Hence the importance of the urine as a guide to health.

How the Urine is Made.—Suppose we imagine the Malpighian body to be in full operation. It is obvious that the glomerulus allows a slow passage of the blood, so that in the delay the filtration of Bowman's capsule can have full scope. We can therefore realize that there is extracted by simple filtration from each glomerulus a steady succession of drops of fluid, concentrated or otherwise, depending upon the state of the blood. As these droplets proceed on their way through the convoluted tubules, they may have added to them other constituents which are derived chiefly from the proteins, and which have been selected by the special cells of the convoluted tubules from the second plexus of vessels already described. This is a secretive action. It may happen, however, that the urine is too watery, i.e. that it has taken too much from the fluid of the blood. This is corrected in the loop of Henlé, where the surplus water is passed back to the blood; the urine then passes on to the pyramids.

How Urine is Collected.—Assuming that the urine oozes out in small drops from the apices of the pyramids into the calices of the kidney-pelvis, it is easily understood how a fairly large drop must collect in the dilated ureter. The individual drops of urine pass down the ureters by peristaltic action, and if we use an instrument called the cystoscope for examining the inside of the bladder, we can observe the urine slowly dripping into the bladder at the ureteral orifices. The bladder thus fills regularly until its capacity is so strained that the reflex of micturition takes place.

Micturition.—The passage of urine is a simple act, prompted by reflexes. There is a certain point at which the transitional epithelium ceases to be "comfortable"; beyond that the symptoms may amount to acute pain. The relief of the bladder is accomplished to a certain extent by voluntary releases of the normal inhibition of the higher centres of the brain. This is accomplished through the pelvic nerves and the sympathetic portion of the hypogastric plexus. It is well known that sudden cold, excitement, fear and so on, quite apart from disease, intensify the afferent impulses and lead to frequency of micturition, but in normal persons urine can be controlled for several hours, although no two individuals are the same. When the act has

commenced, a definite train of events is found, beginning with the opening of the urethra, and going on to relaxation of the sphincter muscles, pressure of the bladder muscles, some abdominal muscle action and finally contraction of the sphincter urethrae.

The Urine

Normal urine is the ideal fluid excrement of the body, but civilization has put so many complexities into the life of the human being that nearly everyone has some metabolic peculiarity, and the urine shows it up. As an indicator, the urine is of supreme importance to the doctor, and since easily recognized abnormalities can be demonstrated in certain diseases, every nurse is expected to be able to test urine for the main constituents.

Normal Urine.—Here, however, we are concerned with normal urine only. The standards expected from an average young healthy adult are as follows.

1. Passage of 3 pints of urine a day. This varies with work, food, perspiration and fluid taken.
2. Acid reaction.
3. Colour, pale amber. There should not be any deposit of solids, but a cloud of mucus is not abnormal.
4. Smell, slightly sweetish or aromatic. An odourless urine, or a urine strongly offensive with ammonia or other gas, is not normal.
5. Specific gravity, 1010–1020.

Constituents of Urine.—Normal urine contains the end-products of protein metabolism, salts and water. In a person taking the normal diet, and doing active work, the following composition should be found:

Water, 96 per cent.

Urea, 2 per cent.

Other solids, 2 per cent. (These consist of uric acid, common salt, sodium, potassium, calcium and magnesium salts, phosphates, urates, ammonia, sulphates, creatinine, hippuric acid.)

Urea has long been recognized as one of the most important factors of the urine, since it results from the metabolism of protein, and gives an investigator some idea of the way in which the proteins are dealt with by the individual. The other constituents may be present as a result of tissue wear and tear, as waste products of vegetables or as excessive minerals. If albumin appears in the urine, it generally indicates that the kidney is damaged: sugar may be a sign of diabetes; blood may also be found.

CHAPTER 20

THE EXCRETORY SYSTEM—THE SKIN

ANATOMY. THE OUTER COAT. THE INNER COAT. SWEAT GLANDS. HAIR FOLLICLES AND HAIR. NAILS. LAMELLATED CORPUSCLES. PHYSIOLOGY. MAIN PROPERTIES OF THE SKIN.

Anatomy

THE skin consists of two coats, an outer and an inner coat.

The Outer Coat.—This is also known as the cuticle, epidermis or protective coat. It is the epithelial part of the true skin which lies below it. Under the microscope, the epidermis is seen to consist of many layers of cells, a true stratified epithelium. The diagram (Fig. 143) indicates clearly how the cells tend to become flattened as they approach the surface until they are worn into flakes and are cast off like scales—the well-known "scurf" of the skin. Skin is always wearing away and always being renewed. It varies in thickness according to the need of the body for protection. Thus the soles of the feet are very thick and hard, and the palms of the hands rapidly acquire a horny layer

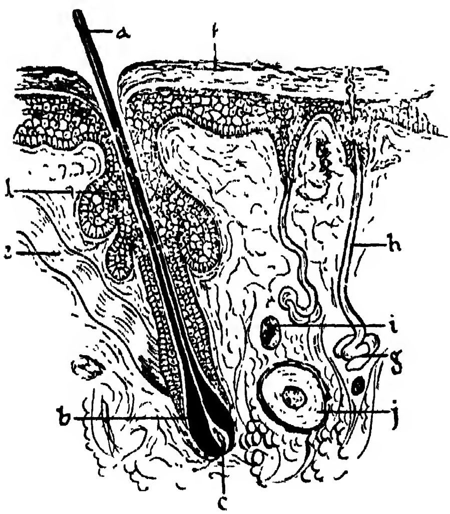


FIG. 143.—DIAGRAMMATIC SECTION THROUGH THE SKIN.

a, Hair. *b*, Bulb of hair. *c*, Papilla of hair. *d*, Sebaceous gland. *e*, Arrector pili muscle. *f*, Hard outer layer. *g*, Sudoriferous gland. *h*, Duct of sudoriferous gland. *i*, Artery. *j*, Lamellated corpuscle.

when much manual labour is done. This consists chiefly of a substance, keratin, which is the least alive of the tissues, since it does not even have a blood supply and is devoid of sensation. Pigment cells are found in the deeper layers of the epidermis.

The Inner Coat.—This is also known as the dermis, cutis vera, or true skin. It is tough and elastic, a stout buffer between the epidermis and the areolar tissue. Both nerves and vessels are freely found, also hair follicles and sweat glands. The structure which is characteristic of the dermis is the presence of papillae set in parallel rows to form ridges. Each papilla is about $\frac{1}{100}$ of an inch high and $\frac{1}{250}$ of an inch broad. In its substance is the tactile corpuscle, a special sensory nerve ending and a plexus of capillary vessels.

Immediately below the dermis is the areolar connective tissue, containing cells, glands, fat and a small amount of fibrous tissue.

Sweat Glands.—These are found chiefly on the palms of the hands and the soles of the feet. They begin as coiled tubes forming small bulbs in the dermis and a thin tube leads up to the surface of the skin. In all there are about 2,000,000 of these glands in the skin.

Hair Follicles and Hair.—The presence of hair is typical of mammals. The amount of hair in the human being varies; the whole surface of the body is covered with it, but in the adult it is in profusion on the head, in the armpits, at the pubic area and buttocks, on the back of the hands and on the legs. The colour of the hair is due to pigment layers in the epidermis. Each hair grows in a follicle, a narrow canal at the bottom of which is the hair papilla, a bulb constantly supplying new epidermal cells from which the hair takes origin. Even if a hair is pulled out, the bulb continues to manufacture a new one, as it is well nourished at its base by lymph. If we look at a hair follicle under the microscope, we see that the root of the hair splits to embrace the papilla. This ensures its nourishment, as it does not have any blood vessel, but, consisting entirely of epidermal material, depends upon the papilla for its life. The oiliness of the hair is due to the presence of sebaceous glands, which are pouches in the wall of the follicle, opening into it by a short duct; these glands contain large cells which provide a rather thick greasy secretion called sebum, which also covers the skin and keeps it flexible and soft. A fine muscle, the arrector pili (literally " the hair raiser ") is also found in the follicle; sudden fear or shock brings it into action (Fig. 143).

Nails.—These are skin appendages, being composed of horny material, growing from a matrix called the " quick," which lies in the nail groove. The whites of the nails (lunulae) are the result of diminution in the number of papillae below.

Lamellated Corpuscles.—In addition to the tactile corpuscles already mentioned, the skin contains nerve endings which look like minute tulip buds, and to which the name lamellated corpuscles, is given. The diagram illustrates their structure (Fig. 143); the centre fibre lies in a clear space, surrounded by concentric layers of connective tissue. The "stalk" is a tributary of a sensory nerve. These corpuscles are concerned chiefly with deep pressure sensations (see also p. 284).

Physiology

Main Properties of the Skin.—There are 6 main properties of the skin, as follows.

1. *Protection.*—Not only does the skin form a covering for the human being; it rounds off corners and it varies its calibre according to the protective or sensory need.

2. *Sensation.*—We have already seen that the skin contains various types of end plates of sensory nerves. These are packed very closely together, giving the property of refinement of heat, cold, touch or pain sense, which is transmitted by the afferent nerves to the brain. Over a dozen varieties of these highly sensitive end organs are known (see pp. 284, 285).

3. *Excretion.*—The outflow of sweat not only assists the kidneys; it is a method of heat loss. As an excretion, it normally goes on insensibly, but if for various reasons it is too apparent, the condition is called sensible perspiration. The nervous regulation of the temperature has already been described on pp. 225 and 226; the automatic control of the sweat ensures that excessive loss is prevented. Sweat itself is slightly heavier than water and is acid, with a characteristic salty taste. It contains a little more than 1 per cent of solids, chiefly aromatic in type, giving the peculiar odour associated with perspiration. On the average, 2 lb. of sweat are lost by an adult in 24 hours.

4. *Heat regulation.*—This has been fully discussed on pp. 225 and 226. Blushing is caused by a suffusion of the skin capillaries; pallor is the opposite condition.

5. *Respiration.*—Carbonic acid gas is found in the sweat, but more must be given off by the surface of the skin. Oxygen is taken up too, so there is ample proof that the skin acts on the same principles as do the lungs.

6. *Absorption.*—That the skin can take up certain greasy substances is proved by the use of inunctions, which are employed in certain cases of illness in order to deliver specific drugs to the blood via the skin.

CHAPTER 21

THE ENDOCRINE SYSTEM

THE DUCTLESS GLANDS. THE PANCREAS. THE THYROID GLAND. THE ACTION OF THYROXINE. MYXOEDEMA. CRETINISM. EXOPHTHALMIC GOITRE. THYROXINE AND THE INDIVIDUAL. THE PARATHYROID GLANDS. THE ADRENAL GLANDS. THE CORTICAL FUNCTION. THE MEDULLARY FUNCTION. ADRENALINE AND ITS USES. THE HYPOPHYSIS CEREBRI. THE THYMUS GLAND. THE PINEAL BODY. CONCLUSION.

PROBABLY no other groups of specialized protoplasm are so important to the human being as the endocrine glands. Small, scattered, apparently insignificant, these organs are of intricate construction, of highly complicated function and of powerful secretion. Collectively their products are known as hormones, substances resembling the vitamins in their action, but distinguished from them by being produced inside the body and not introduced from external sources. Within the present century the whole field of biochemistry has been altered by the discovery of their properties and thousands of papers have been contributed to show their method of action, yet we are still on the fringe of the subject. We know that absence or disease of these minute glands may produce critical changes in the bodily economy, and often death; we know that the giving of synthetic hormones or animal extracts may result in dramatic recoveries; but we know very little about the chemical or the physical nature of the work that goes on. In most cases we are guided simply by the effect of the secretion.

The Ductless Glands

This term is used to designate the several organised endocrine glandular elements situated in various parts of the body which pour out certain hormones into the blood vessels or lymph vessels passing through them. There is no duct; the latter is characteristic of the external secretions. Thus the hormonic extracts are often called internal secretions.

The ductless glands discovered so far are those of the pancreas,

ovaries and testis, which possess other functions, and of the thyroid, parathyroid, adrenal, pituitary, thymus, pineal and certain minor glands. The sex glands are best treated along with the reproductive system (p. 295), but each of the other glands must be studied individually.

The Pancreas.—The structure and external secretion of the pancreas have been fully dealt with (pp. 205 and 206, 220 and 221). The pancreas has an internal secretion also, of great importance. Here and there in the gland tissue can be observed under the microscope groups of cells which appear to vary from the alveolar character of the general tissue of the pancreas. These groups are called the islets of Langerhans, and they secrete the well known substance, insulin (Fig. 144).

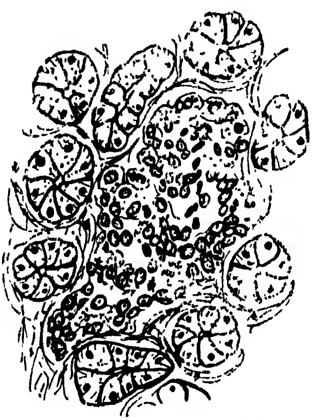


FIG. 144.—THE PANCREAS.
Section showing islet of Langerhans surrounded by alveoli.

The islets of Langerhans are known to contain in their cells two distinct types of granules, which seem to act together to produce an internal secretion necessary for the efficient metabolism of carbohydrate. If the islets are diseased, as in diabetes, sugar in the form of glycogen cannot be stored either in the liver or in the muscles, and so it appears in the urine. Diabetes is therefore an example of fundamental breakdown owing to loss of one internal secretion. Within the past 35 years research has produced an artificial insulin, a commercial product which amply makes good the loss and so relieves the condition of diabetes. The state of the blood sugar is all important in such methods of treatment.

The Thyroid Gland.—This gland lies in front of the trachea, and is roughly H-shaped, the two large lateral lobes being joined together by a narrow isthmus (Fig. 145). It has a liberal blood supply. The histological structure of the gland shows it to consist of numerous wide cavities lined by cells and often containing a thick fluid with blood corpuscles. This fluid is the hormone of the thyroid, containing a powerful substance, thyroxine.

The Action of Thyroxine.—Analysis of thyroxine shows it to contain many of the features of adrenaline, and to be composed of a nucleoprotein and a compound of iodine and globulin. The

effect of thyroxine is to increase general tone. Muscles become more active, more oxygen is used, more sugar metabolized and more heat produced. In every way thyroxine acts as a stimulant, mental as well as physical.

Myxoedema.—Deficiency of thyroxine causes a disease, myxoedema. Every function of the body becomes depressed, and the victim changes entirely in facial character. It is the opposite to the effect we have just described; fat accumulates, hair falls out, the body becomes slow and flabby, the skin is cold, dry and thickened and the general mental acuity is lost, so that the patient appears to be, and is, mentally affected. Graduated doses of thyroid extract produce wonderful changes.

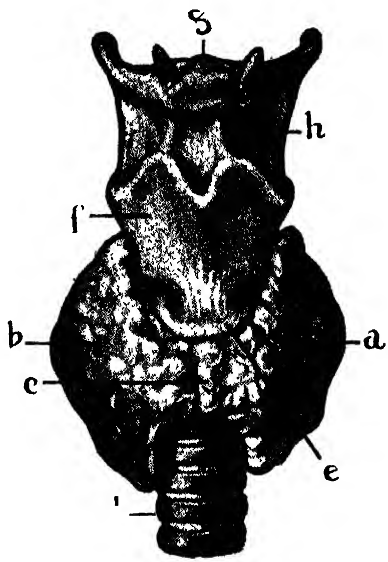


Fig. 145.—The Thyroid Gland.
a, Left lateral lobe. *b*, Right lateral lobe. *c*, Isthmus. *d*, Trachea. *e*, Cricoid cartilage. *f*, Thyroid cartilage. *g*, Hyoid bone. *h*, Hyothyroid membrane.

Cretinism.—If a deficiency of the thyroid gland occurs in infancy, the child usually begins to fail after the 6th month. The condition of cretinism supervenes. It is well known as typical of dwarfs. In size, an adult cretin may have all the characteristics of a child. All development is delayed if not aborted. The muscle tone is poor; fat is abundant; all the systems are sluggish. Thyroxine usually clears up the condition rapidly.

Exophthalmic Goitre.—On the other hand, when the thyroid gland enlarges and produces an increased amount of thyroxine, we find the classical signs of exophthalmic goitre produced. Here the gland may swell to a very great extent, and all the symptoms show excess of tone e.g. prominent eyes, rapid pulse, excitability, sleeplessness, high blood pressure, loss of weight and all the combined evidences of a system working at abnormally great stress.

Thyroxine and the Individual.—A brief reflection on the powers of this hormone will prove its radical influence on the individual. Does the presence or absence of the normal ration make us geniuses or dullards? Undoubtedly thyroxine has a great effect upon our character, as instance the symptoms of myxoedema. It

does not follow that the taking of thyroid extract will make us all brilliant; indeed the dosage of this drug must be carefully considered, and often it is unsuccessful. The real function of thyroxine is to keep us up to our individual standard; it cannot take us beyond the limits primarily ordained in our early embryonic days.

The Parathyroid Glands.—Four glands, each about the size of a millet seed, are found, two on either side of the trachea, but usually so deeply embedded in the substance of the thyroid gland that they are dissected out with great difficulty. Researches have proved that these glands perform a function out of all proportion to their size. Their structure consists of closely packed cells, but sometimes small branching alveoli are found. The blood supply is plentiful.

The main function is control of the calcium metabolism, and since this involves the clotting of the blood, the digestion of milk, the formation of bone and the stimulation of trypsinogen, there is ample evidence of the importance of the parathyroid secretion. Meat, milk and vegetables are all dependent upon parathyroid secretion for their metabolism. Lack of this hormone may expedite the onset of rickets or of a disease of the bones called osteomalacia, which is characterized by softening and fractures, or a spasmodic condition called tetany resulting from lack of calcium in the blood. There is no doubt that the parathyroid secretion and vitamin D work hand in hand.

The Adrenal Glands.—Known also as the suprarenals, these glands are found lying over the upper borders of the kidneys; they have already been described (p. 228). Histologically they how a small, very vascular medulla, and a wide, fatty cortex. This area is further split up by straight capillaries into columns of cells, and further into three zones, named from without inwards, the zona glomerulosa, the zona fasciculata and the zona reticularis (Fig. 146).

The Cortical Function.—Widespread destruction of the adrenal cortex would cause death. Children with tumours of the suprarenal cortex often become giants and show other unhealthy evidences of precocity. Tumours of the cortex in adult women are accompanied by inversion of the secondary sex characteristics; no inversion occurs in men.

The secretion from the cortical portion of the adrenal gland is known as cortin. It controls the levels of sodium and potassium ions in the blood stream. Like calcium, these ions are regulators of permeability in cell membranes, particularly those of the skeletal muscle fibres. In conditions of hypocortinism (Addison's disease) there is a marked decrease in the contractability of these cells, leading to great muscular weakness and a generalized

feeling of acute fatigue. This disease of the cortex is usually associated with destruction of the adrenal glands by tuberculosis. A synthetic preparation, desoxycorticosterone, is usually given in conjunction with sodium chloride to patients with Addison's disease, with good results.

The Medullary Function.—In the medulla are large venous sinuses opening into the efferent vein at the hilum. Between these venous spaces are groups of cells, amply supplied by blood and productive of the indispensable hormone, adrenaline.

Adrenaline and its Uses.—There is an intimate association with the action of the adrenal medulla and the function of the sympathetic system. It is proved that emotion, anger, fear, flight are all accompanied by increase of adrenal supply. The primary action is a constriction of the muscles of the arterial walls, causing a rise of blood pressure. The blood volume is increased; the heart beats with more vim; the spleen discharges more new cells to enrich the blood. The bronchioles are markedly relaxed, an important factor in asthmatic conditions. Heat loss is arrested.

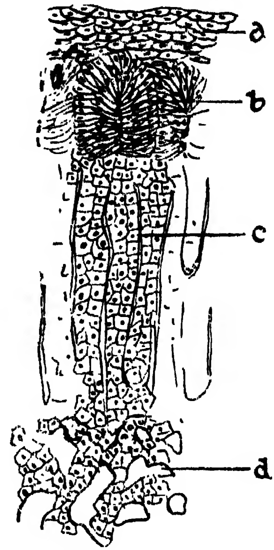


FIG. 146.—VERTICAL SECTION THROUGH CORTEX OF ADRENAL GLAND.

a, Capsule. *b*, Zona glomerulosa. *c*, Zona fasciculata. *d*, Zona reticularis.

Adrenaline as a drug is given very commonly, especially in asthma. It is also useful as a local styptic in small haemorrhages (e.g. in dentistry). It is a well known remedy in shock.

The Hypophysis Cerebri.—This small but important structure, better known as the pituitary body or gland, is found lying on the sella turcica of the sphenoid bone i.e. on the floor of the skull and below the brain. It is about the size of a pea, yet it is essential to life. It consists of three distinct parts, an anterior lobe, a posterior lobe and an intermediate portion.

The anterior lobe shows irregular columns of cells, with a rich blood supply and a certain amount of colloid material. Its function is to control the growth of the body, the development of the sexual organs and to a certain extent the metabolism. When disease is present, gigantism occurs in young people who have not reached maturity, the bones and other tissues rapidly increasing and sexual functions developing early. In the mature

person, the condition of acromegaly occurs; the bones of the face, hands and feet become unduly large, while the skin grows very coarse. In some cases the anterior lobe remains undeveloped, when the condition of infantilism occurs. Types of these cases are frequently encountered; they are characterized by increase of fat, dry skin, sexual immaturity, scanty hair and childlike voice. Very often there is advanced eye defect and weak mental condition. Recent research reports further evidence of important substances influencing the sexual organs of women which have been discovered to be secreted by the anterior lobe of the hypophysis cerebri. These are known as gonadotropic hormones (gonad-stimulating hormones) and are generally referred to as Prolan A and Prolan B; they act on the ovary. Prolan A is said to activate the ripening of the Graafian (vesicular ovarian) follicles, whereas Prolan B is said to control the secretion of the corpus luteum. Another substance which stimulates and causes activity in the fully developed breast is prolactin, secreted by the anterior lobe of the hypophosis cerebri.

The Posterior Lobe.—This contains much nervous tissue and is entirely different from the anterior lobe. It probably arises from the brain. Colloid matter is found. The great function of the posterior part of the gland is the supply of the secretion pituitrin. Experiments show this to contain two substances, vasopressin and oxytocin (pitocin); the former constricts blood vessels, controls the kidneys and affects sugar metabolism; the latter contracts the uterine muscle. Pituitrin is therefore similar in one way to adrenaline, but it has a much more direct effect on the tissues and it is of supreme importance in stimulating the pregnant uterus in midwifery. It may also diminish the secretion of urine.

The Thymus Gland.—In structure this gland consists of a cortex and a medulla, divided up by strands of connective tissue springing from the capsule. Large branched connective tissue cells abound, and they support small cells with large nuclei, rather like lymphocytes. The medulla contains the concentric corpuscles of Hassall. The growth and decay of the thymus gland is interesting. Up to the age of 7 it occupies a distinct position in the thorax about the level of the tracheal bifurcation. After that time it does not increase in size, but at 14 it is usually beginning to degenerate. In the adult only fibrous remnants are seen. In the well known status lymphaticus, children are dull, suffer from adenoids and are generally below standard. The great danger is in giving anaesthetics for an operation; death may occur in an instant, and the subsequent postmortem examination shows an increase of all the lymphoid tissue and of the thymus gland. The normal function of the thymus is (1) to restrain sexual development until puberty; (2) the manufacture of lymph cells.

The Pineal Body.—Some hold that this is the stalk of a missing eye; very little is known of its function. It lies on the base of the brain, is reddish in colour and consists of follicles containing a viscid liquid, in which lime, magnesia and ammonia salts form " brain sand."

Conclusion.—While each ductless gland has its peculiar hormones, there is no doubt that the equilibrium of the bodily protoplasm is governed by the combined action of all. This is a further proof of the interdependence of the tissues and of the compensatory provisions in abnormal conditions.

CHAPTER 22

THE NERVOUS SYSTEM—STRUCTURE AND FUNCTION OF NERVOUS TISSUE

THE FUNDAMENTALS OF NERVOUS ACTION. NERVE TISSUE. NERVE AREAS AND GANGLIA.

THE anatomy of the nervous system properly begins with the microscopical examination (histology) of the basic cells and fibres. These have already been described (pp. 18–20) and the student is recommended to consult these pages from time to time during the study of the pages which now follow.

The Fundamentals of Nervous Action

Taking the nervous system as a whole we find it to be made up of millions of nerve cells with their axons and dendrites, each cell and its processes being known as a neurone. It is impossible to conceive a more perfect or more complex system of intercommunication than that provided by the nerves. Whether the neurones be grouped together to form areas, as in the brain, or their axons bound together to form nerves, the main function is coordination of all the work of the body. The primary stimulus is thought, which, acting through the mind, sets up certain obscure activities in the nerve cells, resulting in some demonstration of energy—the moving of a muscle, the outflow of a secretion, the utterance of a word or the twinkling of an eye. In some cases mind influence is not directly centred on the work being done, but while life lasts the highest thought centres are in control of every activity in the body. Some of the horses of the body, so to speak, run steadily on, controlled only by the eye of the brain, whereas others require constantly the guiding rein. On the other hand, there is a widespread system of receptive stations which pick up the various sensory messages of sight, sound, touch, pain, temperature and so on, and transmit them to the highest centres, where their influences are "registered" and their information acted upon. It is clear that nothing is left undone by Nature to make this system one of perfect coordination and infallible performance.

Nerve Tissue.—Any nerve consists of a bundle of fibres proceeding to or from the cells to which they belong. These

fibres are either white fibres (medullated) or grey fibres (non-medullated); the former dominate the cerebrospinal groups, while the latter are characteristic of the autonomic nervous system. They are bound together by loose connective tissue strands called collectively the perineurium, while the nerve itself has a membranous sheath called the epineurium. A nerve has a dull white or ivory appearance; to the naked eye nerves appear as long elastic threads of variable thickness.

In some cases the nerves are composed of efferent (or motor) fibres, travelling only from the nerve centres to end organs on muscles, glands and other structures; in others the fibres are afferent i.e. going towards the centres (sensory fibres). The former group contains the axons, while the latter are the dendrites. This maintains the one way traffic of the nervous system, in which impulses can travel to a cell only by dendrons and from a cell by axons. It must never be forgotten that the cell proper is the origin of the impulse, while its processes are the conductors of the impulse. It is rarely found, however, that a nerve is purely motor or purely sensory. Usually it is a mixed nerve, containing both motor and sensory fibres running alongside each other, and it may be composed of both medullated and non-medullated fibres. A typical mixed nerve, therefore, might perform the functions of moving a muscle, liberating a secretion from a gland, contracting an arteriole, transmitting sensations of pain, of position, of touch and generally acting as a composite cable of nervous impulse wires running in the same epineurium.

Nerve Areas and Ganglia.—Aggregations of nerve cells occur at various relay posts on the spinal cord, at which junctions, or synapses, occur with the axons and dendrites of associated cells. The substance of the brain is mainly formed of such groups. The ganglia are found in various places—on the spinal nerves, on the cranial nerves and connected closely with the autonomic system. By means of these sub-stations, there is probably a strong reinforcement of impulses in both directions; this will be clearer when we study the physiology of nervous energy later on. Lastly there is a type of fibre which ensures communication between aggregations of nervous tissue; it is chiefly found running in tracts from one part of the brain to the other, and is known as an association fibre.

CHAPTER 23

THE NERVOUS SYSTEM—THE BRAIN

THE CEREBRUM. ANATOMY OF THE CEREBRUM. THE LATERAL VENTRICLES. THE THIRD VENTRICLE. STRUCTURES LYING BELOW THE HEMISPHERES. THE EXTERNAL ASPECT OF THE CEREBRUM. THE LATERAL CEREBRAL SULCUS. THE CENTRAL SULCUS. THE LOBES OF THE BRAIN. THE UNDER SURFACE OF THE BRAIN. HISTOLOGY OF THE CEREBRUM. PHYSIOLOGY OF THE CEREBRUM. THE MAIN MOTOR AND SENSORY AREAS. MAIN NERVE TRACTS OF THE BRAIN. THE CEREBELLUM. FUNCTIONS OF THE CEREBELLUM. THE PONS VAROLII. THE MEDULLA. THE FOURTH VENTRICLE. THE CRANIAL NERVES. MEMBRANES OF THE BRAIN. THE CEREBROSPINAL FLUID.

THE nervous system is divided into two parts: 1. the central, or cerebrospinal nervous system; 2. the autonomic system. The former is the main portion, and consists of the brain, spinal cord and nerves; the latter is made up of certain groups of ganglia and their nerve fibres. In this chapter we are concerned only with the cerebrospinal system, which mainly consists of medullated fibres travelling to muscles under voluntary control and to the various organs of sense. The brain is divided into 5 main parts viz. cerebrum, cerebellum, mid-brain, pons Varolii and medulla oblongata. For the most part, these organs are solid masses of a cheesy looking substance, consisting of nerve cells and their processes, together with the cementing material, neuroglia. Chemically this greyish-white matter is found to consist of albumin, water, certain salts and a predominant amount of phosphorus. The weight of the brain is about 3 pounds; the female brain is lighter, but is probably of greater refinement than the male brain.

The Cerebrum

The cerebrum, as represented in the human being, is the example of the highest perfection in nervous development. Lower animals show elementary nervous systems, and as we ascend the scale the cerebrum is gradually evolved, always acting

as an index of the mental capacity of the creature. Ultimately in man it becomes superlatively important in the scheme of nervous coordination; it is the largest portion of the brain, occupying the major part of the skull and providing for the highest functions of thought and deed.

Anatomy of the Cerebrum.—The first thing that impresses us about the brain is that it is made to fit very closely to the

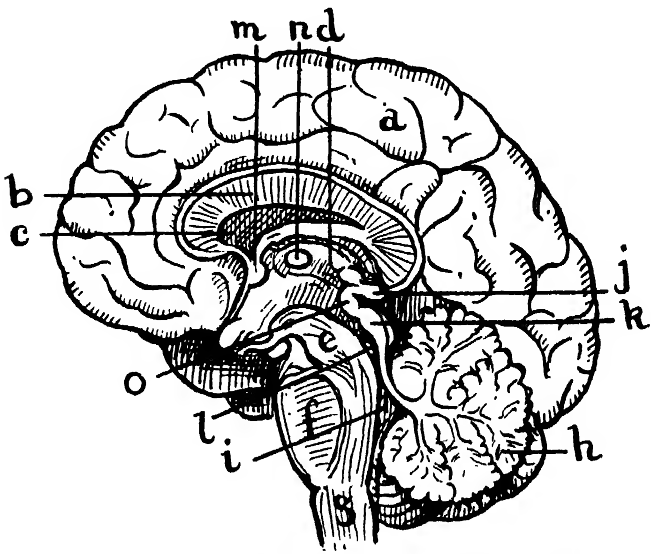


FIG. 147.—LONGITUDINAL SECTION THROUGH THE BRAIN.

a, Cerebrum. *b*, Corpus callosum. *c*, Septum pellucidum. *d*, Third ventricle. *e*, Cerebral peduncle. *f*, Pons. *g*, Medulla oblongata. *h*, Cerebellum. *i*, Fourth ventricle. *j*, Pineal body. *k*, Corpora quadrigemina. *l*, Cerebral aqueduct. *m*, Anterior commissure. *n*, Intermediate mass.

inside of the skull; indeed an examination of the interior of the skull shows clearly how the bone is grooved out like a mould at the parts at which the brain has been in close contact.

The cerebrum resembles the contents of a walnut split longitudinally. The solid dome fills the upper and anterior part of the skull completely. It is divided by a deep central longitudinal fissure into the right and left hemispheres respectively. The surface of the brain is thrown into numerous flattened convolutions or gyri which have deep fissures between them. It is Nature's method of packing as much as possible into a confined space. The outer layer of brain tissue (cortex) consists of grey matter,

while the inner portion is occupied by white fibres. The cerebrum represents 90 per cent of the whole brain. Despite the fact that psychiatric and other clinical and surgical researches seem to indicate that the mass of the cerebrum is not of such great importance as was formerly believed, it is significant that those of great intellectual development have a high and wide forehead, corresponding to the massiveness of the anterior part of the cerebrum.

The two hemispheres are joined together by an isthmus of neuroglia called the corpus callosum. This is apparent when we divide the brain straight through the longitudinal fissure (Fig. 147). We can now see also the inner aspect of the hemisphere. The hollowed cavity roofed over by the mass of the upper brain and the corpus callosum forms with its fellow of the opposite side a chamber which contains 4 distinct recesses viz. 2 lateral ventricles, and the 3rd and 5th ventricles. The last is not a true ventricle, but the first 3 are well defined.

The Lateral Ventricles.—These are situated one in each hemisphere, being separated by a membranous partition, the septum pellucidum. They communicate with each other and with the 3rd ventricle by a passage, the interventricular foramen. The so-called 5th ventricle is between the two layers of the septum pellucidum. An important area on the floor of the lateral ventricle is the thalamus, an oblong mass containing important fibres.

The Third Ventricle.—This chamber is roofed over by the fornix, which is like a spur projecting from the posterior and interior part of the corpus callosum. It is very narrow, its walls bulging medially with the masses of the thalamus. It communicates with the lateral ventricles as described above, while behind it sends a canal to the 4th ventricle. Running across it are 3 bands of tissue, the anterior, middle and posterior commissures (Fig. 147). Its floor is formed by the structures which lie between the two peduncles of the brain, described later. In front it is closed by the anterior pillars of the fornix; behind by the posterior commissure.

Structures lying below the Hemispheres.—The two outstanding features of the mass of nerve tissue lying below the cerebrum are the pons and medulla, and the cerebellum, which enclose the 4th ventricle (see below).

The External Aspect of the Cerebrum.—We must regard the cortex as a great collection of motor and sensory exchange offices; it is an elaborated ganglion. The surface of each hemisphere is divided into areas by the fissures, or sulci, which

are deep and long, leaving islands. These islands are again further subdivided into the convolutions, or gyri, by smaller sulci.

The Lateral Cerebral Sulcus.—This runs obliquely on the under surface of the hemisphere, and turns round at the lower edge to pass upwards and outwards to form the gulf between the frontal and temporal areas (Fig. 148). It is also known as the fissure of Sylvius.

The Central Sulcus.—This passes from the longitudinal fissure downwards and forwards until it almost meets the lateral

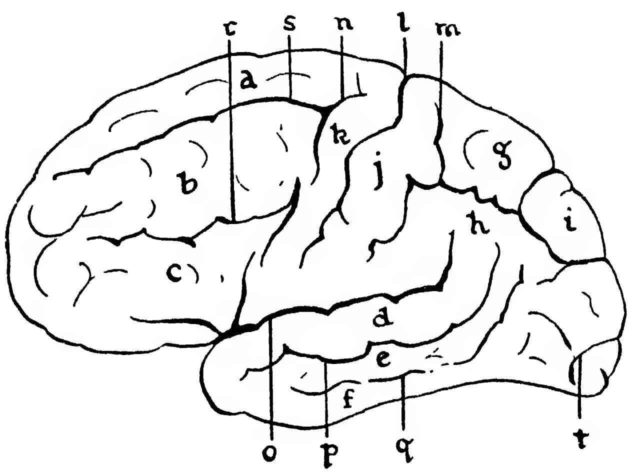


FIG. 148.—THE CEREBRUM. LEFT LATERAL ASPECT.

a, Superior frontal gyrus. *b*, Middle frontal gyrus. *c*, Inferior frontal gyrus. *d*, Superior temporal gyrus. *e*, Middle temporal gyrus. *f*, Inferior temporal gyrus. *g*, Superior parietal lobule. *h*, Inferior parietal lobule. *i*, Parieto-occipital gyrus. *j*, Postcentral gyrus. *k*, Precentral gyrus. *l*, Central sulcus. *m*, Postcentral sulcus. *n*, Precentral sulcus. *o*, Lateral cerebral sulcus. *p*, Superior temporal sulcus. *q*, Middle temporal sulcus. *r*, Inferior frontal sulcus. *s*, Superior frontal sulcus. *t*, Lunate sulcus.

cerebral sulcus. It separates the frontal from the parietal area, and was formerly called the fissure of Rolando (Fig. 148).

The two above mentioned sulci are the chief dividing lines of each hemisphere. Others are shown in the diagrams, which should be carefully studied (Fig. 148 and Fig. 149). It will be noted that not only do they divide the brain into areas, corresponding roughly with the bones of the skull lying over them, but they further subdivide these areas, mapping out the brain into gyri (lobules) and simplifying the geography of the cerebrum

considerably. We recognize the 6 main areas and convolutions described below.

1. *The Frontal Lobe.*—This portion lies in front of the central sulcus and above the lateral cerebral sulcus. It contains 8 gyri (see Fig. 148 and Fig. 149). The most important is the inferior frontal convolution of the left side (Broca's convolution), which is the speech centre.

2. *The Parietal Lobe.*—This has 1 gyrus internally and 3 externally.

3. *The Occipital Lobe.*—This is at the back of the brain. It has 4 convolutions, 3 external and 1 internal.

4. *The Temporal Lobe.*—Three horizontal convolutions are seen on the outer aspect, while 2 are situated on the inner surface.

5. *The Insula.*—The insula or island of Reil is buried in the lateral cerebral sulcus, surrounded by the frontal and temporal lobes.

6. *The Rhinencephalon.*—The rhinencephalon or olfactory lobe lies below the frontal lobe and consists of the members of the olfactory tract.

Every convolution has some important function. As a general rule there is a universal plan for these convolutions, but they vary according to the individual; for example, the gyri of the right hemisphere may not be exactly reduplicated in the left in the same person. For all practical purposes, the above subdivisions are constant, however.

The Under Surface of the Brain.—Looking at the brain from below, there is an apparently bewildering collection of vessels, nerves and other structures. Leaving out the circulatory system and the nerves, the following structures are to be noted (see also Fig. 147 and Fig. 149).

1. The longitudinal fissure, separating the two halves of the brain;
2. The corpus callosum, with its peduncles;
3. The optic chiasma, joining the optic tracts;
4. The tuber cinereum and the infundibulum, the latter joining the hypophysis cerebri;
5. Corpora mamillaria, the ends of the fornix; two small white papules;
6. The hypophysis cerebri;
7. The pons and medulla, the beginnings of the spinal cord;
8. The anterior and posterior perforated substances;
9. The cerebellum;
10. The various lobes of the brain already described.

Histology of the Cerebrum.—The microscope shows 8 distinct layers of nerve cells, all intimately associated, in the cortex of the brain. This arrangement reflects the complex

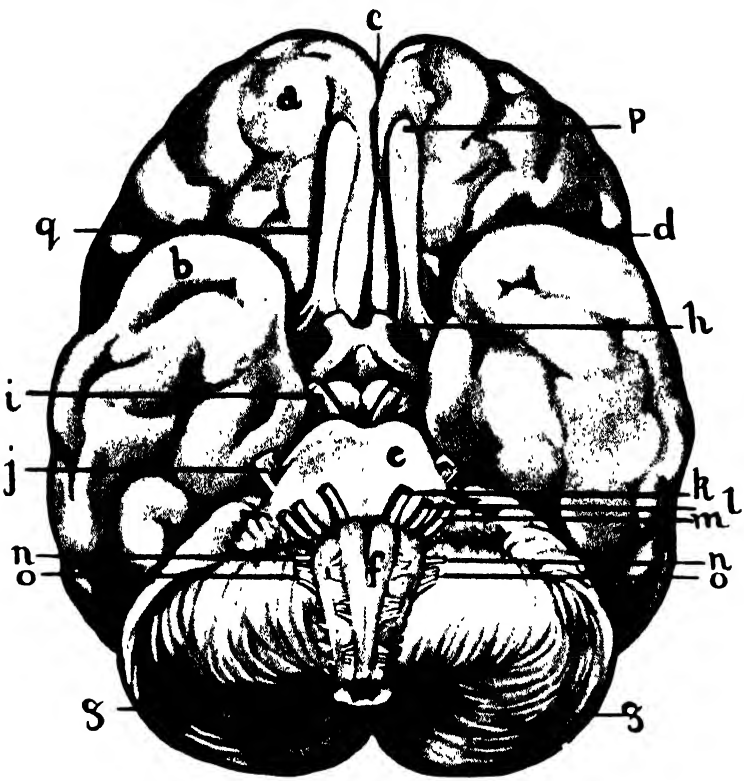


FIG. 149.—THE BASE OF THE BRAIN.

a, Frontal lobe of the cerebrum. *b*, Temporal lobe of the cerebrum. *c*, Longitudinal cerebral fissure. *d*, Lateral cerebral sulcus. *e*, Pons. *f*, Medulla oblongata. *g*, Cerebellum. *h*, Optic nerve. *i*, Oculomotor nerve. *j*, Trigeminal nerve. *k*, Abducent nerve. *l*, Facial nerve. *m*, Auditory nerve. *n*, Glossopharyngeal nerve. *o*, Vagus nerve. *p*, Olfactory bulb. *q*, Olfactory tract.

nature of the work done. In some gyri the cells are more simple than in others; everything depends upon the function of the area involved. The cells are of all sizes, but typically triangular in shape, with axons and dendrites as communicating links. The basal ganglia are specialized groups of centres resembling ganglia elsewhere. They are found close to the insula, and represent the primary developmental centres of the brain. The cortex becomes embedded in white matter and forms certain "islands" of grey matter which are very important. The most prominent are

1. The corpus striatum, with the caudate and lenticular nucleus;
2. The claustrum;
3. The optic thalamus.

The white matter forms the main tracts of the brain, and consists of bands composed of the elements mentioned below.

1. Association fibres, passing from one district to another on the same side;
2. Commissural fibres, communicating by the corpus callosum and the commissures with the hemisphere of the opposite side;
3. Projection fibres, passing by the corona radiata to the spinal cord. These are the massed axons of the various nerves of the body (Fig. 150).

Physiology of the Cerebrum.—Much has yet to be learned about the function of the brain. The highly developed cerebrum of the human being places him above all other creatures; man is supreme by reason of his intellect, which resides in his highest and most delicate centres, dictating laws, morals, methods of communication and new ideas. We strive to maintain a steady improvement in the average standard of racial intellect by developing the parts of the brain which are at the root of our supremacy in the world, but it must be confessed that while we know a certain amount about the functions of one area or another, there are still many so-called silent areas about which we are ignorant. We are dependent upon injury or disease for our data, and these are comparatively rare in the brain. Sometimes a discovered defect of a silent area is accompanied by mental impairment; at other times nothing happens. Within the past few years, surgical operation on the frontal lobe (e.g. for the removal of tumours) has produced unbelievably good results, more especially in the realms of mental efficiency. Improvements of an unexpected nature have taken place. Apart from this, there has been a vogue, in certain suitable types of mental disease, for the operation of prefrontal leucotomy (lobotomy), with excellent effect. It is therefore somewhat difficult to lay down any clearly established principles so far as the physiology of the upper regions

of the brain are concerned. At one time it was considered that even the slightest damage to a small part of the frontal cortex would produce results mentally and physically of a seriously degenerative kind; lately ideas have had to be revised.

The Main Motor and Sensory Areas.—Centuries of careful study and demonstration have resulted in the mapping out of the brain into certain definite areas, corresponding to the functions of the body. If we destroy these small groups of cells, we destroy the appropriate function, thus in certain diseases it is possible to say with some certainty where the damage is situated in the brain.

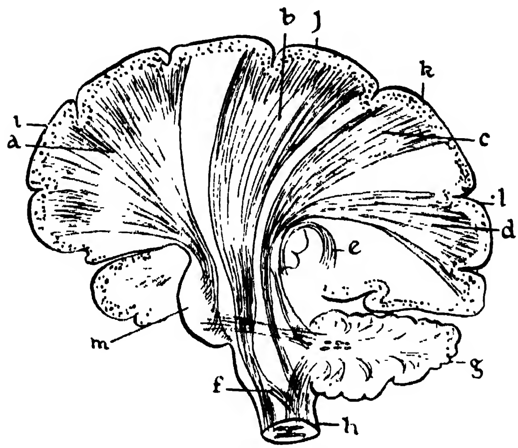
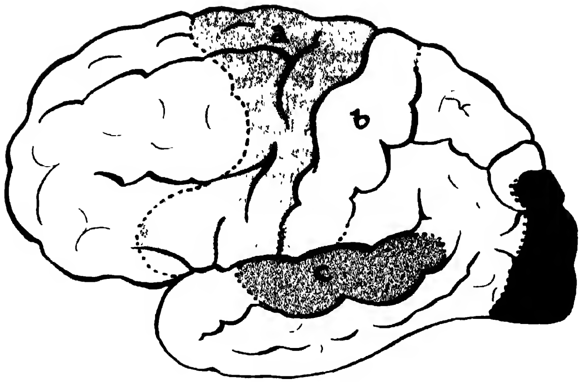


FIG. 150.—LONGITUDINAL SECTION THROUGH THE BRAIN, SHOWING THE CHIEF TRACTS.

a, Tract from frontal gyri to pons and thence to the cerebellum. *b*, Motor pyramidal tract. *c*, Sensory tract (touch). *d*, Visual tract. *e*, Auditory tract. *f*, Motor decussation in the medulla. *g*, Cerebellum. *h*, Medulla oblongata. *i*, Frontal part of cerebrum. *j*, Central part of cerebrum. *k*, Parietal area. *l*, Occipital part of cerebrum. *m*, Pons.

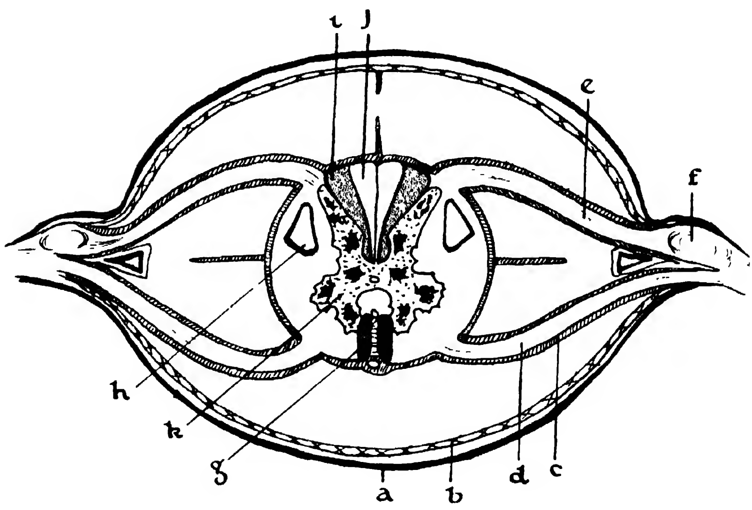
First of all it is well to realize that the cerebrum is the seat of the sensations, receiving at its cortical areas all the afferent stimulations of touch, shape, weight, sight, smell, hearing, hunger, thirst and numerous other messages. It also originates the motor functions, which control the movements of the body, our speech, our expressions. It is the birthplace of the intelligence, the emotions, the will, memory and everything connected with our thoughts—consciousness, subconsciousness, mental control.

In mapping out the areas of the cerebrum (Plate XIV, A), we are faced with the fact that nearly two-thirds of the cerebrum are "silent" areas, centres of psychical activity and little understood.



A. THE CHIEF SURFACE REGIONS OF THE BRAIN.

a, Motor area *b*, Tactile and muscle sense *c*, Hearing. *d*, Vision.



B. TRANSVERSE SECTION THROUGH THE SPINAL CORD SHOWING MEMBRANES AND CHIEF TRACTS.

a, Dura mater. *b*, Arachnoid. *c*, Pia mater. *d*, Anterior nerve root. *e*, Posterior nerve root. *f*, Spinal ganglion. *g*, Anterior cerebrospinal tract. *h*, Lateral cerebrospinal tract. *i*, Fasciculus cuneatus. *j*, Fasciculus gracilis. *k*, Grey matter, showing cell centres.

The greater part of the frontal lobe is a silent area (see above). It is responsible for the behaviour of the individual, his conduct and his character. It is the " brain " in the popular sense. Its importance is proved by the elaborate system of association fibres passing to all the other vital areas, and by projection fibres which proceed to the optic thalamus. The motor area is situated in front of the central sulcus and is mapped out as shown on Plate XIV, A. Behind the central sulcus is the region of tactile and muscle sense—what we are able to perceive when our eyes are shut. Vision is centred at the occipital area, while hearing is in the superior temporal gyrus. The speech centre is above the lateral cerebral sulcus, close to the centre of taste and smell. There are numerous association fibres in front of the occipital area and above the temporal area.

Main Nerve Tracts of the Brain.—Our conception of the brain cortex is now one of a mass of cells of all types, communicating with each other, sending out motor impulses for all practical purposes or receiving sensory messages, the whole process very much involved, and arranged so that every cell of the brain is aware of the work of its fellows. Coordinate action is thus assured.

The white matter is composed of groups of nerve fibres, and so important are these that we can map out the course they take in the brain. Thus the area in front of the central sulcus gives origin to the great pyramidal tracts, which eventually distribute their fibres to the spinal cord and so to the nerves running to every part of the body. If we wish to move the index finger, there is activity of a minute area of cells in the corresponding region of the cortex, and the resultant stimulations are sent down by this route. The motor area passes through two important regions—the corona radiata and the internal capsule. The latter is a very important region, since the fibres are closely packed here and are liable to injury in haemorrhage from the artery which passes close to them. Sensory fibres, and those of sight and hearing, are present too, so that the whole internal capsule acts like a narrow pass allowing the fibres to travel both upwards and downwards. It is clear why injury of the cortex no bigger than a pin head may cause paralysis of a finger, but the slightest pressure in the internal capsule e.g. by haemorrhage, causes paralysis of a limb or limbs and interference with many of the sensory functions. In dealing with the spinal cord later on we shall find that most of the pyramidal fibres cross over to the other side, and this phenomenon is exemplified in injuries to the brain, when the limbs of the side opposite to the lesion are paralysed. There are numerous other tracts composed of groups of fibres connecting different portions of the brain, but it is not necessary to discuss them in this work.

The Cerebellum

The cerebellum is literally " lesser brain." It lies in the post-cranial fossa of the skull, situated below the occipital lobe of the brain, and behind the pons and medulla. It consists of 2 lobes joined by a fibrous band, the vermis, and like the cerebrum, is made up of a mass of white matter covered by a cortex of grey matter. There are no convolutions in the cerebellum, the surface being ridged and furrowed alternately. If a section is cut we see a peculiar arrangement of grey and white matter, which gives a tree-like character to the mass, hence the name "arbor vitae" (Fig. 151). There are several layers of cells and numerous connecting fibrous tracts, bringing the cerebellum into communication with the cerebrum, muscles, limbs, ears, skin and other structures.

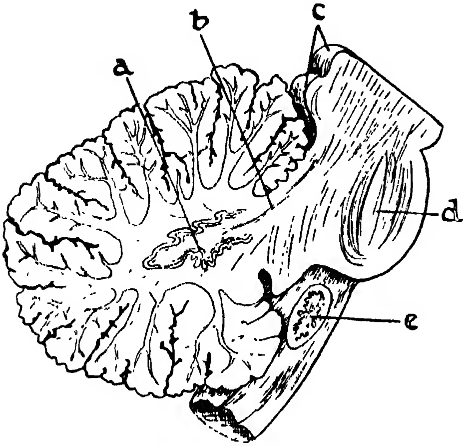


FIG. 151.—LONGITUDINAL SECTION THROUGH THE CEREBELLUM.

a, Dentate nucleus or trunk of arbor vitae. *b*, Superior cerebellar peduncle. *c*, Corpora quadrigemina. *d*, Pons. *e*, Medulla.

Functions of the Cerebellum.—The work done by the cerebellum may be summed up in the one word, coordination. The balance of the body, the maintenance of the equilibrium, the position sense and everything connected with the smooth running of the machine are controlled by this part of the brain. Harmony is assured, so that complex acts like walking, cycling, drinking a cup of tea, each of them involving community action on the part of the muscles, are made possible and with the greatest refinement. Injury, poisoning or disease of the cerebellum produces the condition of ataxia, temporarily demonstrated by those suffering from indiscreet overdoses of alcohol. As far as we can make out, the cerebellum obtains the raw products of muscle action from the cerebrum and manufactures them into complex evolutions. Without it, our muscular system would be a riotous collection of independent strands, contracting and expanding

apparently without rhyme or reason. The tone would be poor, there would be tremor, and a general weakness of the flesh would occur.

The Pons Varolii

This portion of the brain connects the cerebrum with the cerebellum, and also with the medulla oblongata. Fibres pass over its anterior, saddle-like surface to become merged in the substance of the lateral hemispheres of the cerebellum. The two stalks (crura) of the brain arise from its upper surface to continue its longitudinal fibres into the cerebrum. In the substance of the pons are several scattered portions of grey matter, the nuclei of the 5th to 8th cranial nerves and other nuclei. The ascending and descending tracts passing through are split up into bundles by the transverse fibres of the pons. The function of the pons is chiefly that of a conductor of fibres from the brain to the spinal cord (Fig. 147 and Fig. 149).

The Medulla

The medulla oblongata, or bulb, is the part of the brain immediately preceding the spinal cord. It is about an inch long and narrows as it joins the true cord; its grey matter is inside the white matter. Its lower border is almost flush with the rim of the foramen magnum. Owing to its numerous important nuclei and to its narrow cable which later becomes the spinal cord, the medulla is the most vital part of the brain. Destruction of even a part of the medulla may cause instant death. Here are found the centres of breathing, heart-regulation, swallowing, vomiting and sweating, as well as the nuclei of the 9th to the 12th cranial nerves.

The Fourth Ventricle.—Most of these vital centres are found on the floor of the 4th ventrical, otherwise the posterior aspect of the medulla. The 4th ventricle is the cavity formed by the medulla in front and the cerebellum behind; it communicates with the third ventricle by the cerebral aqueduct (aqueduct of Sylvius) above, while below it is continuous with the central canal of the spinal cord. It is filled with cerebrospinal fluid. Puncture of the floor of the 4th ventrical is certain to destroy more than one vital area. Physiologically it is a centre concentrating all the functions indispensable to life.

The Cranial Nerves

It will be noted that we have mentioned already the origins of 12 pairs of nerves arising direct from the brain. These

are either mixed nerves, motor nerves or sensory nerves and to them we give the name cranial nerves (Fig. 149). The cranial nerves are briefly described below in order; roman numerals have been retained, since these particular nerves have always been distinguished by this method.

I. *Olfactory Nerve.*—The olfactory nerve, nerve of smell, a sensory nerve, consists of a number of filaments which originate in the mucous membrane of the nasal cavity and pass upwards through the cribriform plate of the ethmoid bone. It joins the olfactory bulb of the frontal lobe, which in turn joins the olfactory tract of the brain, situated on the under surface of the temporal lobe.

II. *Optic Nerve.*—The optic nerve, the nerve of sight, is a sensory nerve. Its fibres originate in the retina of the eye. Coursing backwards through the optic foramen of the orbit to the base of the brain, the optic nerve forms, with its partner of the opposite side, the optic chiasma, which lies in the optic groove of the skull. Here a small decussation of the fibres with both sides takes place, and the re-formed tract, now known as the optic tract, passes backwards on the surface of the brain to the interior of the brain, reaching the optic thalamus and then the occipital region of the cerebral cortex (visual centre).

III. *Oculomotor Nerve.*—The oculomotor nerve, a motor nerve, supplies 4 of the 6 muscles which move the eyeball. It emerges from the ventral side of the mid-brain and passes into the orbit through the superior orbital fissure.

IV. *Trochlear Nerve.*—The trochlear nerve (trochlear, from the Latin *trochlea*, a pulley) is a motor nerve and supplies one muscle only of the eyeball—the superior oblique muscle. It arises from the dorsal aspect of the mid-brain and from there it winds round it to pass into the orbit through the sphenoidal fissure.

V. *Trigeminal Nerve.*—The trigeminal (Latin, meaning *three born together*) is sensory to the face and motor to the muscles of mastication. It emerges from the ventrolateral aspect of the pons and then widens to form the semilunar (trigeminal or gasserian) ganglion, which lies on the floor of the middle cranial fossa; here it divides into three main branches described below.

1. The opththalmic branch (a sensory nerve only) which emerges from the skull to pass through the sphenoidal fissure to supply the forehead and front half of the scalp and the anterior portion of the eyeball (conjunctiva);

2. The maxillary branch (a sensory nerve) emerges from the skull through the foramen rotundum and then gives off branches which supply the upper lip, the upper teeth, the lower eyelid, the front portion of the cheek and the temporal region;

3. The mandibular branch (mixed nerve) passes out through the foramen ovale, innervates the masseter tem-

poralis and pterygoid muscles (motor), the inner surface of the cheek, part of the skin of the cheek and the temporal region. A lingual branch supplies the mucous membrane of the tongue and another, the inferior dental nerve, supplies the lower teeth, skin of the chin and lower lip.

VI. *Abducens Nerve.*—The abducens, a motor nerve, innervates the external rectus muscle of the eyeball.

VII. *Facial Nerve.*—The facial nerve is a motor nerve supplying the muscles of facial expression and providing sensory fibres (the chorda tympani) of taste for the anterior $\frac{2}{3}$ of the tongue. It emerges from the brain at the lower portion of the pons accompanying the abducens nerve.

VIII. *Auditory Nerve.*—The auditory nerve (acoustic nerve) emerges from the brain at the lower level of the pons, and enters the internal auditory meatus to pass to the internal ear. It consists of 2 portions: (1) the cochlear or nerve proper of hearing; (2) the vestibular or nerve of equilibration. Both pass from the internal auditory canal to the medulla.

IX. *Glossopharyngeal Nerve.*—The glossopharyngeal is a mixed nerve. Its motor fibres pass from the medulla through the jugular foramen and supply the muscles of the tongue and pharynx. Its sensory fibres convey sensations of taste from the tip and back portion of the tongue.

X. *Vagus Nerve.*—The vagus nerve (pneumogastric) is a mixed nerve. It arises from the ventrolateral aspect of the medulla and passes out of the skull by the jugular foramen. It proceeds into the neck, thorax and abdomen and innervates the larynx, heart, lungs and part of the abdominal viscera with motor and sensory fibres. Most of the vagus nerve belongs to the parasympathetic nervous system. It regulates the action of the heart and the act of swallowing. It is the sensory nerve supply of the respiratory tract from the larynx downwards and of the alimentary tract from the pharynx to part of the intestinal tract.

XI. *Spinal Accessory Nerve.*—The spinal accessory nerve arises from the ventrolateral aspect of the medulla and passes through the jugular foramen along with the 9th and 10th cranial nerves. Its action is purely motor; it innervates the sterno-cleido-mastoid and trapezius muscles.

XII. *Hypoglossal Nerve.*—The hypoglossal nerve arises from the ventral aspect of the medulla. It sends motor fibres to the muscles of the tongue and those linking the latter with the jaw and hyoid; it also innervates the ribbon muscles of the neck.

Membranes of the Brain

The brain is invested by 3 membranes, disposed as follows. The covering next the brain is called the pia mater, a very

delicate connective tissue of fine mesh, liberally supplied with blood vessels, which nourish the brain tissue; it dips down into the fissures, covering the surfaces of the convolutions. The next membrane is the arachnoid (" like a spider's web "); this is a serous membrane, consisting of bundles of fibrous and elastic tissue, which are based on a transparent reticulum. The arachnoid membrane does not dip into the sulci, therefore it leaves a space which is filled with cerebrospinal fluid secreted from its under surface and which is called the subarachnoid space. Covering the arachnoid is a tough, thick resistant membrane, obviously protective in character, known as the dura mater; its outer surface is in contact with the inner table of the skull, where it is closely applied as a form of periosteum. It is plentifully supplied with vessels and nerves. The dura mater also lines the spinal canal, and, as we have already noted, forms the boundaries of the venous sinuses surrounding the brain. It has two chief folds. One hangs down like a curtain between the 2 cerebral hemispheres, and because it is like a sickle is called the falx cerebri. The other is horizontal, forming a roof or tentorium over the cerebellum. These folds give support and strength to the brain substance, keeping the organ in place.

The Cerebrospinal Fluid

The cerebrospinal fluid is found in the subarachnoid space. It also originates in the lateral ventricles and passes by the aqueduct of the mid-brain to the 4th ventricle; then by piercing the pia mater there, it reaches the cerebral cavity, whence it is filtered through to the blood. The average amount of cerebrospinal fluid is about 150 cubic centimetres. It acts as a cushion for the brain and spinal cord, protecting the nerve centres from concussion. It normally consists of water, salts and glucose, with a small amount of protein, which increases in disease. The presence of blood cells in the cerebrospinal fluid is indicative of disease of the brain or its membranes (meninges) and therefore in cerebrospinal meningitis the investigation of this fluid is most important.

CHAPTER 24

THE NERVOUS SYSTEM—THE SPINAL CORD AND NERVES

THE SPINAL CORD. MEMBRANES OF THE CORD. INTERNAL STRUCTURE. THE GREY MATTER AND THE SPINAL NERVES. TRACTS OF THE CORD. THE MOTOR NERVE PATH. THE SENSORY NERVE PATH. THE FUNCTIONS OF THE SPINAL NERVE ROOTS. THE SPINAL NERVES. THE CERVICAL REGION. THE CERVICAL PLEXUS. THE BRACHIAL PLEXUS. THE THORACIC REGION. THE LUMBAR PLEXUS. THE SACRAL PLEXUS. PHYSIOLOGY OF NERVOUS ACTION. NERVE FORCE AND ITS TRANSMISSION. REFLEX ACTION. SLEEP.

THE brain ceases to exist at the foramen magnum, at which level the medulla oblongata merges into the spinal cord proper. The latter, safely protected by the spinal canal and its membranes, runs down for about ⅔rds of the whole length of the spine, giving off numerous spinal nerves and roots at each vertebral level.

The Spinal Cord

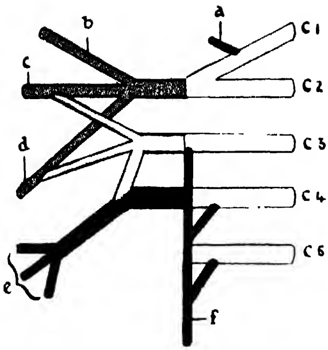
The spinal cord runs like an electric cable down the central canal formed by the superimposed vertebrae. It is the direct prolongation of the fibres from the brain and medulla and it is a great highway for the nerve tracts, allowing stimuli to pass up and down to and from the brain. In addition to this, there are numerous groups of cells at various levels, these forming relay stations and ensuring that messages are efficiently transmitted. The cord is about 18 inches long and ½ inch in diameter. This width is not uniform; at 2 places there is an enlargement corresponding to the increased concentration of fibres viz. the cervical enlargement and the lumbar enlargement. Roughly speaking, the spinal cord extends from the upper border of the atlas to the lower border of the first lumbar vertebra. At its lower end it branches in a peculiar way, the filaments resembling a horse's tail, hence its name, cauda equina. The termination of the cord is thus cone-like, and there is a central filament which persists and passes on to the end of the canal; this portion is known as the filum terminale.

Membranes of the Cord.—All the membranes associated with the brain are continued down the cord, so that 3 layers of tissue invest it in its entire length, protecting it securely against jolts and concussion and bathing it in cerebrospinal fluid. The pia mater is fitted very closely to the cord, supplying it with blood. The arachnoid membrane, however, is not attached to the pia mater, but is a separate, somewhat loosely applied sheet of serous tissue, the inner aspect of which is the boundary of the subarachnoid space, containing the cerebrospinal fluid. The dura mater represents only the meningeal part of the dura mater of the brain. It is not applied closely to the vertebrae, but is fixed by strands of loose fibrous or areolar tissue, which allows free movement of the cord when the back is bent. Small tags of fine fibrous tissue run from the dura mater to support the pia mater on either side (Plate XIV, B).

Internal Structure.—The naked eye appearance of a cut section of the cord shows it to have grey matter centrally and white matter at the periphery, but in order to gain a full knowledge of the internal structure it is best to describe a transverse section examined under the microscope after it has been stained in the usual way (Plate XIV, B). Here we find the section to be almost circular, with a minute central canal almost invisible to the naked eye. This runs down the entire length of the cord, from the fourth ventricle. The grey matter is arranged in H-shaped masses, the outline being somewhat like that of a butterfly. The white matter is split up into distinct columns which occupy well defined tracts around the grey matter. Two indentations are noticed, one anteriorly and one posteriorly. These are called the anterior and posterior fissures. The anterior fissure is a small, shallow, V-shaped depression, but the posterior fissure is simply a thin layer of connective tissue interposed like a partition.

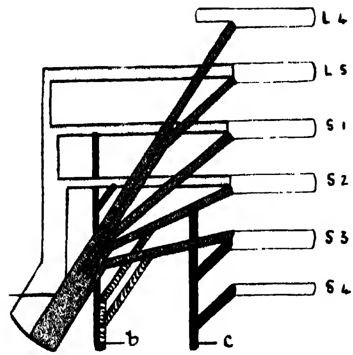
The Grey Matter and the Spinal Nerves.—It should be noted that the grey matter resolves itself into 2 distinct areas, called cornua, or horns. The anterior horn and the posterior horn thus form well marked projections of the grey matter on either side of the cord. The narrow isthmus of grey matter which joins the two lateral masses is called the grey commissure. At its middle is the small central canal (Plate XIV, B).

The spinal nerves emerge as 31 pairs, coming off on either side of the spinal column at the intervertebral levels. There are 8 pairs in the cervical region, 12 in the thoracic, 5 in the lumbar, 5 in the sacral and 1 in the coccygeal region. They pass through the intervertebral foramina. The method of formation is simple and constant. Each nerve arises by an anterior and a posterior root, which has origin in the corresponding cornua of the cord. The anterior horn gives off the anterior



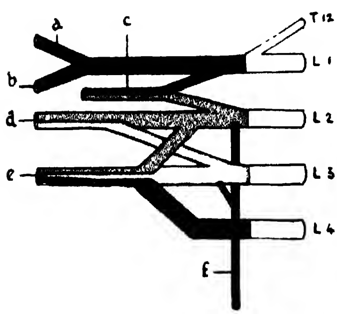
A. The Cervical Plexus.

a, To vagus. *b*, Smaller occipital. *c*, Great auricular. *d* Cutaneous cervical. *e*, Supraclavicular. *f*, Phrenic.



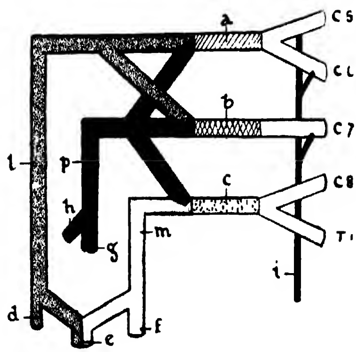
B. The Sacral Plexus.

a, Sciatic. *b*, Posterior femoral cutaneous. *c*, Pudendal.



C. The Lumbar Plexus.

a, Iliohypogastric. *b*, Ilioinguinal. *c*, Genitofemoral. *d*, Lateral femoral cutaneous. *e*, Femoral. *f*, Obturator.



D. The Brachial Plexus.

a, *b*, *c*, Nerve trunks. *l*, Lateral cord. *p*, Posterior cord. *m*, Medial cord. *d*, Musculocutaneous. *e*, Median. *f*, Ulnar. *g*, Radial. *h*, Axillary. *i*, Long thoracic.

DIAGRAMS ILLUSTRATING THE FOUR MAIN PLEXUSES.

root, which is a motor one, while the posterior horn gives off the posterior root, which is a sensory one. As these roots pass out from the cord they leave small lateral indentations on the cord. Shortly after it leaves the cord, the posterior root is provided with a well defined ganglion, called the posterior root ganglion, and this lies in the intervertebral foramen. These ganglia contain cells which send out 2 processes (bipolar cells); one goes back to the spinal cord while the other goes on with the spinal nerve, which is formed immediately after by the junction of the anterior and posterior roots. It must be borne in mind that the direction of the impulses in the posterior root is sensory (towards the brain), whereas the direction in the anterior root is motor (from the brain). Immediately after the two roots unite, the nerve emerges from the spine and almost at once splits up again into two divisions, the anterior and posterior primary rami. These are mixed nerves. The posterior rami send nerves to the skin and muscles of the back. The anterior rami may contribute to the nerve plexuses, which are discussed below, but in the thoracic region they run on to form the thoracic nerves. Generally speaking, anterior rami are the bases of the nerve supply for the neck, front and sides of trunk, arms and legs. They have connecting filaments with the sympathetic system.

Tracts of the Cord.—The grey matter consists of superimposed layers of cells, sometimes occurring in definite columns, together with their interlaced axons and dendrites. Four distinct regions can be mapped out, as indicated in the diagram (Plate XIV, B), but this does not represent all the work that is going on. We must imagine that the whole stalk of the grey matter is a mass of cells, receiving the stimulations from axons through arborizations and passing them on either to the brain or to the tissues.

The white matter consists almost entirely of columns of fibres representing the telegraph wires of the system. Again we can divide up the white matter into distinct areas as represented on the diagram (Plate XIV, B).

The Motor Nerve Path.—This is represented by the anterior cerebrospinal tract (direct pyramidal tract), the lateral cerebrospinal tract (crossed pyramidal tract) and some others, which have influence on group movement, equilibrium, the eye, the blood vessels and various other structures.

The Sensory Nerve Path.—This is found chiefly posteriorly, where the principal columns are known as the fasciculus gracilis (formerly tract of Gall) and the fasciculus cuneatus (formerly tract of Burdach). The functions represented are senses of touch, pain, temperature, position and so on.

In the above paths provision is made for the communication between brain and end organ. There are 2 neurones in the motor path, known as the upper motor neurone and the lower

motor neurone respectively. The upper motor neurone begins in one of the giant cortical cells of the precentral area. The axons travel through the corona radiata and the internal capsule to the medulla. Here the majority of the fibres cross, although some go straight on, forming the two distinct paths mentioned above. Ultimately they arborize round an anterior horn cell. The lower motor neurone now begins. A cell of the anterior horn sends out, by the anterior root to a spinal nerve, axons conveying the stimuli to the motor end organ of a muscle. The ascending paths have 3 neurones. The first takes the sensation from the skin, using an axon from a bipolar ganglion cell on the posterior root; reaching the ganglion it transfers its stimuli to the other cell axon, which, using one of the ascending tracts, reaches the medulla, where it forms a second arborization round a nucleus cell found there. The next relay post is at one of the basal ganglia already described. The axon of the second neurone again arborizes with a basal ganglion cell, and finally the third neurone sends its axon to one of the sensory areas of the cortex, where the message is registered and acted upon. The sensory fibres vary in their methods of crossing; some do not cross until they reach the medulla; others cross as soon as they enter the cord at the posterior root.

The Functions of the Spinal Nerve Roots.—Proof of the activities localized in various parts of the cord is provided in experimental section of the roots which spring straight from the grey matter. For instance, if we divide the anterior roots which are known to end in a particular area such as the foot, all action of the muscles involved will stop, although sensation will remain unaffected. The foot will be in a state of flaccid paralysis. By passing a certain type of electric current along the distal portion of the cut root (the part in touch with the limb), a contraction of the muscles will occur, similar to that produced when a movement is in progress. This proves that the anterior roots are motor roots and that the stimuli go out from the cord. In confirmation of this, we have only to apply the current to the central cut portion, when no result will be obtained, either of movement or of sensation, showing that no afferent impulses travel by that route.

Similar tests with the cut posterior roots will show parallel results. Thus the stimulation of the distal end will have no effect on the limb, the muscles of which are not paralysed, but the central end will respond with marked sensations of pain, which had been lost in the whole of the area supplied by the nerve under investigation. It is therefore proved that the posterior roots are entirely sensory roots, with impulses travelling to the cord.

From the above facts it is easy for us to understand that when there is injury or severance of the spinal nerves themselves, both movement and sensation will be lost or interfered with, since these

nerves are mixed nerves. The irritation of a cut nerve may give the impression that the pain is in the limb itself; this is a common experience in those who have a limb amputated, and is known as referred pain. The latter is also important in connection with the abdominal organs, most of which have peculiar nerve associations in that irritation of their substance may be transferred to some area of the skin; e.g. in gallstones the pain is frequently referred to the right shoulder.

The Spinal Nerves

Of the 31 pairs of nerves emerging from the spine, we already know that the posterior rami form the nerves for the back. The anterior rami form the intercostal nerves in the thoracic region, but otherwise the anterior rami become involved in rather intricate junctions known as plexuses. Of these, 4 are important, and in our study of the spinal nerves from above downwards, each will be reviewed in turn.

The Cervical Region.—There are 8 pairs of cervical nerves. The upper 4 anterior rami form the cervical plexus; the lower 4, with the first thoracic anterior ramus, form the brachial plexus. The posterior rami give off several small cutaneous nerves including the greater occipital nerve.

The Cervical Plexus.—This has 10 branches, 6 deep and 4 superficial. It lies in the upper part of the neck, covered by the sternomastoid muscle. The best way to gain a good knowledge of the nerve plexuses is to draw them again and again; the diagrams should therefore be studied carefully and copied if need be. It will be noted (Plate XV, A) that the 4 anterior divisions C1 to C4 unite and give off their 10 branches, as detailed in the diagram. The phrenic nerve is the most important branch, since it runs to the inferior surface of the diaphragm to supply that muscle,

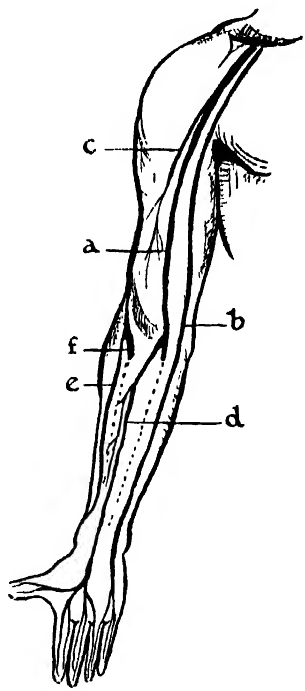


FIG. 152.—NERVES OF THE ARM (ANTERIOR).

a, Median. *b*, Ulnar. *c*, Musculocutaneous. *d*, Volar interosseous. *e*, Radial superficial branch. *f*, Radial deep branch.

as well as the pericardium and pleura. It communicates with the coeliac plexus of the sympathetic system.

The Brachial Plexus.—This is on a level with the cervical enlargement, and represents the basis of nerve supply for the upper extremities. It is situated between the neck and the prominence of the shoulder, and is very complex in structure. The diagram (Plate XV, D) shows how the plexus is formed and how it divides. The first arrangement is one of three trunks, formed by C5, and C6, C7, and C8 and T1. These are referred to as a, b and c. The next stage is the formation of the three cords—lateral, posterior and medial. The lateral cord is formed by a slip from b and a slip from a ("l"). The posterior cord is formed by slips from a, b and c ("p"). The medial cord is formed by a prolongation from c ("m"). These three cords again divide; "l" goes on as the musculocutaneous nerve, but sends a slip to join the medial cord, "m"; "p" goes on giving off various lateral branches, finally splitting into the circumflex and radial nerves; "m" runs on to be joined by the slip from "l" to form the median nerve, while it divides up just before this to give off the ulnar nerve. These are the main terminations of the brachial plexus, but it must be noted that certain nerves to the muscles of the neck and shoulders, the skin and other structures (4 above the clavicle and 7 below) are given off as well, the whole forming a widespread network of nerve trunks running to all the structures of the neck, shoulder and arm regions.

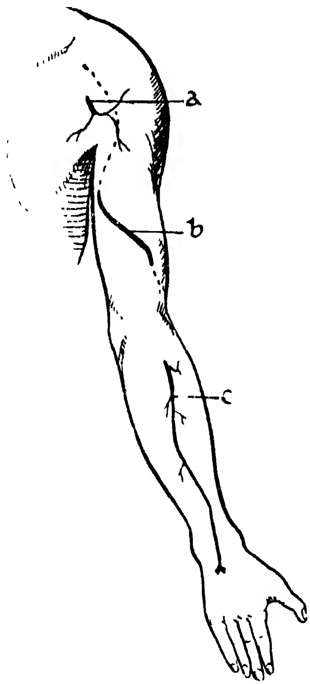


FIG. 153.—NERVES OF THE ARM (POSTERIOR).

a, Circumflex or axillary. *b*, Radial. *c*, Deep branch of the radial.

The musculocutaneous nerve runs down the lateral aspect of the arm after piercing the coracobrachialis muscle, to supply the biceps and other structures of this area.

The axillary or circumflex nerve winds round the head of the humerus, supplying the deltoid muscle, teres minor and the skin and integument of the shoulder joint.

The radial nerve takes the course of the radial (musculospiral) groove in the humerus, winding round to the lateral side of the arm and giving a branch to the triceps. At the front of the lateral epicondyle it supplies sensory trunks for the lateral regions of the forearm and hand and gives off the posterior interosseous branch, which not only supplies the wrist joint, but with three exceptions all the muscles of the radial side and back of the forearm. It is thus vitally important in wrist-drop, which is a paralysis of the extensors of the wrist and fingers.

The median nerve crosses from the medial to the lateral aspect of the brachial artery and runs down the upper arm until it reaches the pronator radii teres, under which it gives off numerous cutaneous and muscular branches. It then goes down the middle of the forearm to terminate on the palm of the hand, supplying the flexors and pronators of the wrist and fingers as well as the skin of the lateral side of the palm of the hand.

The ulnar nerve supplies the deep wrist flexors, the elbow and wrist joints, the skin of the medial half of the hand and the majority of the lesser muscles of the hand.

The Thoracic Region.—The posterior divisions of these pass backwards between the transverse processes and divide into external and internal branches, which supply both the skin and muscles of the back. The anterior rami give rise to 12 pairs of intercostal nerves, of which the upper 6 supply the chest wall, while the lower 6 supply the lower chest and the abdomen, one branch reaching as far as the skin over the greater trochanter.

The Lumbar Plexus.—This is a comparatively simple plexus, derived from the 12th thoracic and upper 4 lumbar nerves (Plate XV, C). Its situation is in the psoas muscle, in front of the lumbar transverse processes. It corresponds to the lumbar enlargement and provides for the nervous supply of the lower extremity. The 2nd, 3rd and 4th lumbar nerves are chiefly involved, their anterior rami dividing as shown in the diagram to form the following chief branches: the iliohypogastric and ilio-inguinal nerves and the genitofemoral nerve from T12, L1 and L2. These supply the skin of the hip, lower abdomen and the various structures of the generative organs.

The lateral femoral cutaneous nerve (L2 and L3) is distributed to the anterior, posterior and lateral parts of the skin of the thigh.

The obturator nerve springs from L2, L3 and L4. It passes through the obturator foramen to supply the adductor muscles of the thigh, hip and knee, some of the skin of the thigh and leg, and the obturator externus muscle. Occasionally there is a separate accessory obturator nerve from L3 and L4.

The femoral nerve (L2, L3, L4) is the chief branch of the

lumbar plexus. It gives off branches to the psoas, iliacus and pectineus, and passing below the inguinal ligament comes to the front of the thigh in the femoral triangle (Fig. 154). Immediately afterwards it spreads out in the shape of a fan and sends branches

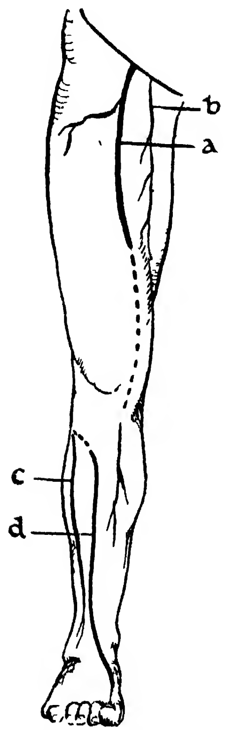


FIG. 154.—NERVES OF LEG (ANTERIOR).

a, Femoral. *b*, Anterior branch of obturator. *c*, Musculocutaneous. *d*, Anterior tibial.

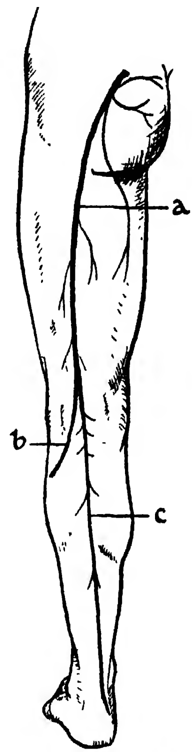


FIG. 155.—NERVES OF LEG (POSTERIOR).

a, Sciatic. *b*, Lateral popliteal. *c*, Posterior tibial.

to the quadriceps extensor, the skin of the front of thigh, knee and leg, the sartorius muscle and the knee joint.

The Sacral Plexus.—The lumbosacral cord, derived from the 4th and 5th lumbar nerves, unites with the anterior divisions of the upper 3 sacral nerves. This plexus lies on the pyriformis muscle (Plate XV, B). After giving off muscular branches to the glutei and tensor fasciae latae, and to the skin of the perineum

and hip, it divides into two nerves—the pudendal (which supplies the perineum, anus and genital organs) and the sciatic nerve. The sciatic nerve is the biggest nerve in the body; it is as broad as the little finger and stretches down the back of the pelvis from the greater sciatic foramen to the back of the thigh. It passes under the biceps and finally divides just above the knee joint posteriorly into the lateral and medial popliteal nerves, which become the anterior tibial and musculocutaneous nerves and the posterior tibial nerve respectively, below the level of the popliteus muscle. The sciatic nerve thus supplies the whole of the muscles and most of the skin of the leg and foot. It gives articular branches to the hip, muscular branches to the flexors of the leg, over which it lies in the thigh, and by its terminal branches to every structure below the knee (Figs. 154 and 155).

Physiology of Nervous Action

What is the force which is the basis of all nervous energy? It is not electricity, but it is something resembling it in many respects, and the passage of an electric current along a cut nerve induces an action in the relative muscle which is similar to that obtained when we are dependent upon the stimulations from the cortical cells. Another analogous property is proved by the fact that nerves react briskly to all types of electrical treatment; in fact the only remedy which has had any success in the treatment of many advanced nervous diseases is electricity applied in various ways.

Nerve Force and its Transmission.—Whether the nerves are specially tuned by receiving local " currents " from the cell or no, there is no doubt that thoughts give rise, in the giant Betz cells of the precentral area, to some stimulus which resolves itself into a sustained series of impulses travelling at the rate of about 200 feet per second. The only evidence of moment in the cell is the activity and increase of the Nissl's spindles; this gives some index of the work done by the cell. A cell does not work by itself; there is always group action, and owing to the comprehensive system of dendrite communication, coordination and cooperation of the cortical section is the rule. The path chosen by a motor impulse is known to be the corona radiata, the internal capsule, crura, mid-brain, pons and medulla, after which it may take the direct or the crossed pyramidal tract and run down one of the white columns of the spinal cord to a certain level, at which it branches off to pass through an arborization round an anterior horn cell (synapse), and so is transmitted to a spinal nerve and finally to the end plate of a muscle, at which its message is delivered to the muscle cells.

In the sensory fibres the impressions of limb position, of move-

ment, of shape, of pain, touch and temperature and the messages from the organs of special sense travel in a direction opposite to that of the motor impulses. Whether the fibres cross immediately they reach the cord or wait until they are higher up depends upon their function. The general principle of sensory impression is a primary stimulus from one of the various end plates or corpuscles on the skin or in the eye, ear, nose or tongue. The special senses are considered later. The impulses from the skin travel via one of the bipolar axons towards its parent cell in a posterior spinal root ganglion, the other axon taking the sensation onwards to one of the ascending tracts until the optic thalamus is reached. This may be called the concentration area for all sensory impulses, which are further relaid through fresh synapses to the various parts of the cortex reserved for them.

Reflex Action.—In certain cases, the spinal cord is allowed to judge for itself, and although it does not possess the properties of the cortical nerve tissue, it has a definite mechanism, called reflex action, which permits it to deal with reactions which are practically instantaneous. There is a certain amount of control, or limitation of reaction, from the brain above, but very often reflex action becomes so much a matter of custom that we are unaware it is going on. For example, if we touch a very hot plate we at once withdraw the hand before we are aware we have done it; there is no evidence of voluntary control.

The essential elements of reflex action are as given below.

1. A receptor organ—sensory bulb on the skin; the retina and other areas.
2. A sensory path, running from receptor organ through posterior root ganglion to posterior horn cells.
3. Spinal cord grey matter—in this the stimuli are transferred from posterior root to anterior root.
4. Anterior horn cells, transmitting the impulse into the motor efferent tract in the anterior root.
5. The efferent nerve.
6. The effector organ, or end plate, on the muscle involved.

The above system is known collectively as the reflex arc. If the spinal cord is cut completely across above the levels of this arc, paralysis of both movement and sensation will occur, but the reflex arcs will remain intact and will operate, although somewhat altered in type.

Examples of spinal reflexes are the group known as the tonal reflexes, which keep the muscles alert for any emergency—fight, flight, protection and so on; those for defaecation, micturition and parturition (the lumbar centres); and certain sweat and vasomotor mechanisms. All these are said to be inhibited by the brain but come into action when the inhibition is relaxed.

Many other reflex actions occur quite apart from our consciousness, however, and they are represented by certain aspects of the activities of our everyday life e.g. walking, dressing, reading, breathing and many other vital functions. It is our method of protection to depend upon our lower centres for the subconscious reactions which occur in a flash and which continually keep us free from disaster. It is simply another of many

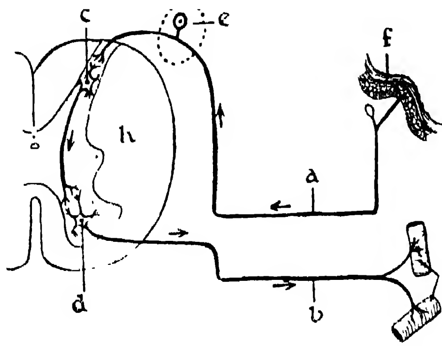


FIG. 156.—DIAGRAM OF A REFLEX ARC.

a, Sensory nerve fibre. *b*, Motor nerve fibre. *c*, Posterior horn cell. *d*, Anterior horn cell. *e*, Posterior root ganglion. *f*, Skin. *g*, Muscle fibres. *h*, Spinal cord.

demonstrations that Nature has amply provided us with the weapons to maintain our protoplasm in an extraordinary state of refinement (Fig. 156).

Sleep.—The desire to sleep is shown by heaviness of the eyelids; muscular fatigue; dullness of the mind, the senses and the general activities of the body. The rate of the heart is reduced; the temperature tends to fall. Gradually this passes into the complete unconsciousness of sleep, in which all the vital functions are depressed except the excretion of sweat and the rate of digestion. These two during sleep are uninhibited in vasomotor supply. The first 4 hours of sleep are the most profound, after which sleep gradually becomes lighter. Many theories have been advanced to show how sleep occurs, but most are unsatisfactory. It is probable there is a biochemical reason for the need of the brain cells to suspend operations for a few hours. Certainly there are well marked chemical changes in the body fluids during sleep.

CHAPTER 25

THE NERVOUS SYSTEM— THE AUTONOMIC NERVOUS SYSTEM

THE SYMPATHETIC SYSTEM. THE GREAT PLEXUSES. PHYSIOLOGY OF THE SYMPATHETIC SYSTEM. THE PARA-SYMPATHETIC SYSTEM. PHYSIOLOGY OF THE AUTONOMIC SYSTEM.

THE word autonomic means "self governing." This does not infer that the autonomic system is independent of the cerebro-spinal system. It rather indicates that the organs are controlled by nerves which have a certain property of maintaining independent action of the organ, so that it is practically unaffected by the will and uninfluenced by the controlling mechanism of the muscles of the limbs and various other structures. There are 2 divisions of this system—the sympathetic, or thoracico-abdominal system, and the parasympathetic system, which comprises the cranial and sacral sympathetic nerves.

The Sympathetic System.—The sympathetic system of nerves consists of a chain of ganglia, connected by nervous strands, and giving off numerous fibres to other ganglia associated with them. The thoracico-abdominal chains lie on either side of the spinal column, or over it, stretching from the base of the skull to the coccyx. They are in communication with the spinal nerves by grey and white rami communicantes; indeed the origin of all the sympathetic fibres is the central nervous system, although very little is known about them. The 2 chains terminate in front of the coccyx in one ganglion—the ganglion impar. Three great plexuses are associated with the thoracico-abdominal chains viz. the cardiac plexus, the solar or coeliac plexus and the hypogastric plexus. In the head there are 2 important plexuses—the internal carotid plexus and the cavernous plexus. In the cervical region 3 ganglia are known as the superior, middle and inferior cervical ganglia respectively. In the thorax 11 or 12 ganglia occur; they lie on the heads of the ribs. While the nerves springing from the upper ganglia communicate with the cardiac plexus, those from the lower 7 form 3 main trunks, known as the greater, lesser and lowest splanchnic nerves, running to the coeliac plexus. In the abdomen there are

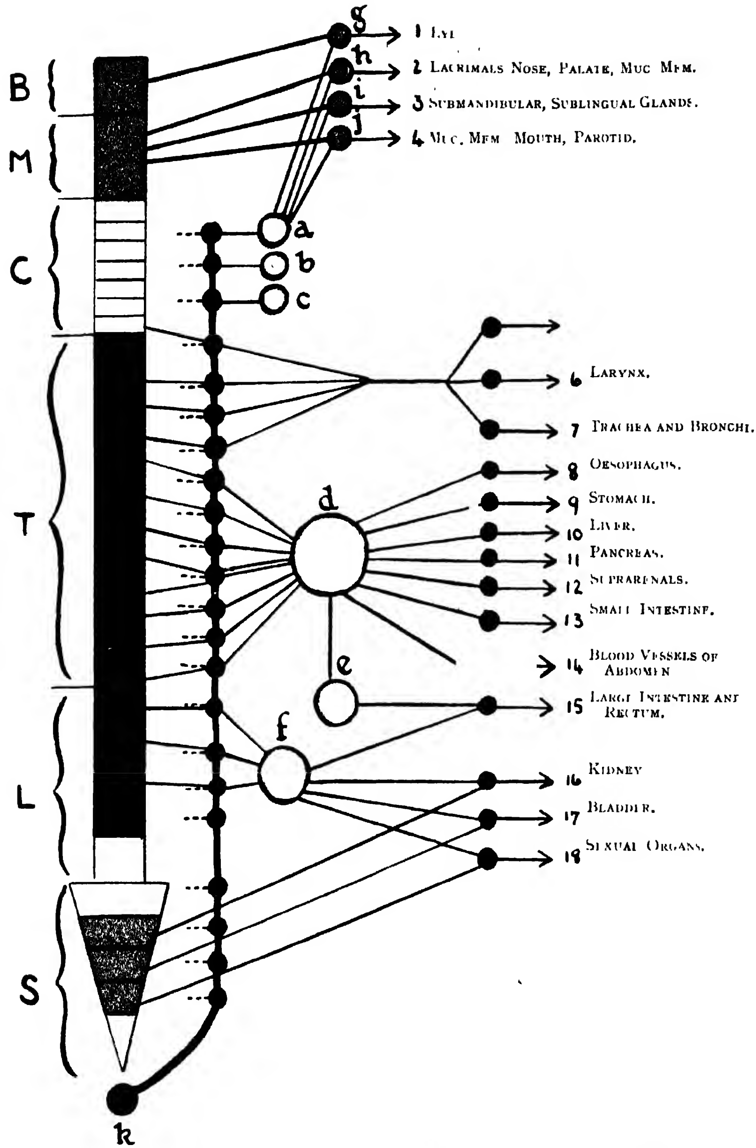


DIAGRAM OF THE AUTONOMIC NERVOUS SYSTEM.
SHOWING GANGLIA AND CONNECTIONS.

B, Brain. *M*, Mid-brain. *C*, Cervical region. *T*, Thoracic region. *L*, Lumbar region. *S*, Sacral region.

4 lumbar ganglia on each side; in the pelvis, the pelvic ganglia are similar in number and are situated on the front of the sacrum; they communicate with the pelvic plexus by several offshoots.

The Great Plexuses.—The 3 great plexuses of the sympathetic, with their secondary plexuses supplying the viscera of the cavity concerned, are situated in the thoracic, abdominal and pelvic cavity respectively.

1. The cardiac plexus is at the base of the heart and is divided into a deep and a superficial cardiac plexus. From these are formed the coronary plexuses and other minor groups.

2. The solar plexus, also known as the coeliac or epigastric plexus, is often referred to as the " abdominal brain." It is an intricate mass of ganglia and nerves lying behind the stomach and in front of the diaphragm. It has about 10 secondary plexuses associated with it and is of great importance to the kidneys, spleen, liver, aorta and stomach.

3. The hypogastric plexus divides into 2 pelvic plexuses, forming secondary plexuses to the pelvic organs (Plate XVI).

The Parasympathetic System.—The fibres originate from 2 areas—the cranial area and the sacral area. In the former the centres are the mid-brain and medulla, while in the latter they are the 2nd, 3rd and 4th sacral segments. The fibres run in the 3rd, 7th, 9th and 10th cranial nerves, and the 2nd to 4th sacral nerves. The ramifications, however, are spread over a very wide field embracing the vital parts of the body. A characteristic is the presence of a ganglion, often very small, for each nerve. Thus the oculomotor nerve has the ciliary ganglion; the facial nerve, the sphenopalatine and submandibular ganglions; the glossopharyngeal nerve, the otic ganglion. The vagus nerve actually does not have any ganglion, but there is a minute bulb on the walls of the various viscera to which the nerve is distributed. The sacral parasympathetic nerves unite with branches of the pelvic sympathetic plexuses and are known as the nervi erigentes, supplying rectum, bladder, uterus and the erectile tissues (Plate XVI).

Physiology of the Autonomic System.—It is known that the erector muscles of the hair, the sweat glands, the sebaceous glands and the muscles of the blood vessels are innervated by the sympathetic, which should be regarded as a stimulator of acceleration or work augmentation of the part supplied. But there is no " pure " sympathetic supply; we must consider the parasympathetic as antagonistic to it and always available. Two possible combinations are distinguished: 1. sympathetic + cranial parasympathetic; 2. sympathetic + sacral parasympathetic. One set of fibres antagonizes the other. Thus it is common to have to one organ distinct inhibitory and accelerator

nerves (e.g. the vagus and sympathetic to the heart). The iris of the eye is dilated by the sympathetic, constricted by the oculomotor nerve. The salivary glands have a double supply as also the lacrimal gland, the pancreas and the bile-forming part of the liver. The alimentary canal has a vagal tonic effect and a sympathetic relaxation effect. In the pelvis a similar state of affairs exists in the organs. In the skeletal muscles the tone and nourishment are thought to be under sympathetic influence. The sympathetic influence radiates from a vaso-motor centre, while the parasympathetic system (acting through central nervous system trunks) is governed by a vasodilator centre. Many important autonomic centres have been discovered at the base of the brain. The autonomic fibres of the sympathetic associated with the cerebrospinal fibres bring about the phenomenon of referred pain, already mentioned. With this there may be pallor of the affected part, tenderness and even muscular spasm.

A great deal has yet to be discovered about the work of the autonomic systems. Our knowledge is still very imperfect.

But the chemical changes brought about by the substances adrenaline and acetyl choline, either in the ganglia at the junction of the grey and white rami communicantes or at the nerve terminations, seem to suggest that very soon many difficult problems of nervous and vascular physiology will be solved.

CHAPTER 26

SPEECH, AND THE ORGANS OF SPECIAL SENSE

SPEECH. VOICE. HOW SPEECH ORIGINATES. THE EYE. ANATOMY. THE COATS OF THE EYEBALL. THE INDIVIDUAL CONSTITUENTS OF THE EYEBALL. APPENDAGES OF THE EYE. PHYSIOLOGY OF THE EYE: OPTICS. THE EAR. THE OUTER EAR. THE MIDDLE EAR. THE TYMPANIC MEMBRANE. THE INTERNAL EAR. PHYSIOLOGY OF HEARING. THE SENSE OF SMELL. THE ORGAN OF SMELL. PHYSIOLOGY OF SMELL. TASTE. CIRCUMVALLATE PAPILLAE. FUNGIFORM PAPILLAE. FILIFORM PAPILLAE. THE TASTE BUDS. HOW TASTE IS PERCEIVED. TOUCH SENSATION.

SPEECH is one of the higher cerebral functions, and is difficult to classify in the order of study of the nervous system, therefore it is dealt with before the organs of special sense, to which it has a certain relationship. The organs of special sense are those of the eye, the ear, the nose, the tongue and the skin.

Speech

Speech depends upon two mechanical properties. First the lungs and the larynx cooperate in sending air through the glottis thus setting up vibrations in the vocal cords. Secondly the tone set up is modified by the cavities of the throat and mouth and formed into letters and words by the tongue, teeth and lips (see p. 186 for anatomy of larynx). The arytenoid cartilages form with the cricoid cartilage 2 joints, and the true cords stretch from the thyroid in front to the arytenoids behind. If these cords are stretched, the cords approach one another, so that a slit—the "chink" of the glottis—is formed. This is accomplished by the action of the cricothyroid muscle, which tends by its contraction to rotate and thus to force the arytenoid cartilages slightly backwards, but sufficient to render the cords taut. The crico-arytenoids open and close the glottis. The thyro-arytenoids, when contracting, shorten the vocal cords but increase the internal tension. Of the 5 muscles connected with the cord, therefore, 3 open and close the glottis, and 2 influence the tension of the cords.

Voice.—Pitch depends upon rate of vibration. Middle C in music is 256 vibrations per second, and the number of vibrations increases or decreases according to whether we raise or lower the pitch. The four strings of a violin give different notes not only in pitch but also in quality, because the strings are of varying thickness and material. Similarly if we can modify the thickness of the cords by stretching or relaxing, we can change the pitch, and the notes can be altered. In deep bass singing the cords and the arytenoid cartilages are in vibration together, but high notes are produced by a maximum thinning of the cords. In ordinary middle register only the cords vibrate. Females and boys have smaller and finer voice boxes than males, hence the higher pitch. Vowels are sounds proceeding from the larynx in which the overtones are accentuated by putting the mouth and throat into various shapes. Consonants like "d" and "t" are produced by the tip of the tongue on the back of the front teeth, and are known as dentals; gutturals are "g" and "k," made by the tongue on the palate; labials are "b" and "p," made by the lips.

How Speech Originates.—Four different processes are involved, 2 afferent and 2 efferent. Vision and hearing convey the impressions to the cortex, while the efferent actions are either speech or writing. Any interference with these paths results in some defect of language, oral or written; in fact, there are 8 possibilities, which need not be discussed here, the condition being described by the term, aphasia. Broca's convolution, a part of the inferior frontal gyrus and long thought to be the only speech centre, is now known not to have this distinction; no doubt several paths and centres are involved.

The Eye

The eye, like the other special sense organs, is a very sensitive, highly developed and complex arrangement of tissue for the reception of a specific sensory stimulus. It is a type of organ composed of a multitude of cells having the highest function, and is capable of wonderful adjustment and perception, ensuring that the sensation of light is transferred to the particular part of the brain dealing with the interpretation of all the visual phenomena. The cranial nerve associated with the eye is the second (II) or optic nerve.

Anatomy.—The essential structure is a globular mass called the eyeball, which with its muscles, glands, nerves, blood vessels and other constituents, occupies the cavity of the orbit in the skull. The eyeball is not a true globe; in outline it takes the form shown in Fig. 156, the bulge in front being due to the cornea. The average eye measures 1 inch in diameter in the antero-

posterior direction, but slightly less from side to side It is impermeable to light except at the front, where there is a circular " window " for the passage of light.

The Coats of the Eyeball.—From without inwards, 3 distinct coverings constitute the eyeball.

1. The sclerotic coat is on the outside; it is the " white " of the eye, forming a tough, resistant casing all round it, except at the front, where it gives place to the cornea, the latter occupying about one-sixth of the surface.

2. The chorioid coat is a vascular membrane over which are spread like a net the branches of the ophthalmic artery. It has pigment cells, which determine the colour of the iris. The latter is continuous with the chorioid coat and may be blue, brown or grey according to the individual. The chorioid coat ends in front by becoming the ciliary bodies.

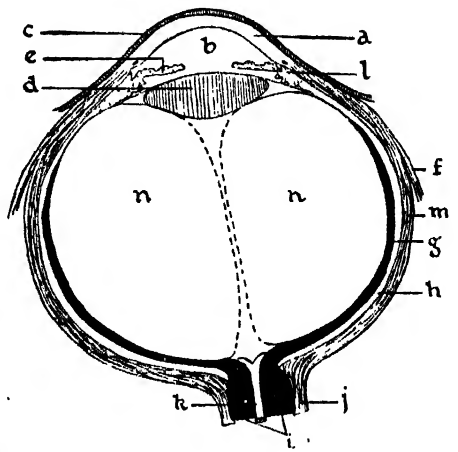


FIG. 157.—HORIZONTAL SECTION OF EYEBALL

a, Cornea. *b*, Anterior chamber. *c*, Conjunctiva. *d*, Lens. *e*, Iris. *f*, Lateral rectus muscle. *g*, Retina. *h*, Chorioid. *i*, Optic nerve. *j*, Nerve sheath. *k*, Artery. *l*, Ciliary body. *m*, Sclera. Vitreous body.

3. The retina is the inner lining of the eyeball. Over its surface the terminal filaments of the optic nerve ramify among special cells. There is a disc-like spot, marking the entrance of the optic nerve, allowing the passage of vessels and unprovided with retinal elements. This is called the " blind spot " or optic disc (Fig. 157). The retina is about $\frac{1}{100}$ inch thick. If we regard the eyeball as a camera, the retina occupies the position of the film or plate upon which rays are focused. The colour of the retina, a delicate purple, is due to the presence of a pigment known as rhodopsin, which fades in the presence of strong light. The optic disc is slightly to the medial side of the centre of the back of the eyeball. The centre of the retinal surface, directly opposite the middle of the cornea, is yellow in colour and at its centre slightly depressed. It is called the macula lutea, while its depression is known as the fovea centralis. This small area is the

most sensitive of the eye, dealing with the majority of the rays passing through and provided with the thinnest retinal coat. The retina is built up of a series of special cells, known as the rods and cones (Fig. 158). This system represents the machinery for translation of light impressions from the eye to the brain. In all eye diseases the above retinal landmarks are most important in diagnosis.

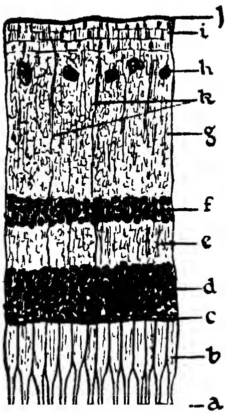


FIG. 158.—SECTION OF RETINA.

a, Pigmented layer. *b*, Layer of rods and cones. *c*, Membrana limitans externa. *d*, Outer nuclear layer. *e*, Outer plexiform layer. *f*, Inner nuclear layer. *g*, Inner plexiform layer. *h*, Ganglionic layer. i. Stratum opticum. *j*, Membrana limitans interna. *k*, Sustentacular fibres.

The Individual Constituents of the Eyeball.—1. *Muscles.*—These are tabulated on p. 107. Their action is to move the eyeball as a unit in all directions. In nearly all cases 2 or more muscles work in conjunction.

2. *The Cornea.*—The cornea is very like the window of a diver's helmet, or the porthole of a ship's cabin. It consists of layers of flat cells, forming a clear transparent bulge on the front of the eye (Fig. 157). It is a tissue which is very much alive; although it has no blood supply it is abundantly provided with nerves. In outline it is like a small inverted watch-glass set over the front of the eyeball. It is constantly bathed in fluid supplied by the blood vessels of the sclerotic coat.

3. *The Iris.*—If we look at the eye from the front, we see a black disc, the pupil, surrounded by an outer ring of coloured tissue, the iris. This structure has many of the properties of the diaphragm of a camera, cutting down the aperture when necessary. The iris is hung like a curtain attached to the ciliary bodies formed by the edge of the chorioid coat (Fig. 157). The pigment cells lie in two layers behind the iris, but they are also scattered about in its protoplasm, so that when light is shed on the iris the peculiar coloration is demonstrated. Certain people (albinos) do not have any coloration, the result of absence of pigment cells, and they show the pink tints of the blood in the chorioid behind. The iris is made to contract or expand by two sets of muscles arranged like a spider's web. The sphincter pupillae is represented by the concentric threads, while the dilator pupillae is formed by the radiating strands. The pupil is thus said to dilate or to contract, although it is really the iris which is in action. The term is used for convenience, and the facts are most vital in many abnormal conditions. The pupil may be as small

as ·05 inch in diameter or as great as ·4 inch. It has a double supply through the oculomotor nerve, which contracts the pupil, and the sympathetic, which dilates it (see p. 272).

Pupils contract if a bright light is shining, but they also react similarly in fixing the eye on near objects (accommodation). In the dark the pupils are at their widest, or during fright or surprise.

4. *The Lens.*—Like the lens of a camera, the lens of the eye is placed just behind the iris. It is a crystalline structure, made up of layers of cells forming an organ very like an onion in composition. It is biconvex, but slightly flattened in front, where the iris is closely applied, and measures about ⅓ inch across. The lens is enclosed in a transparent capsule, from which it can easily be shelled out. This capsule acts as a sort of suspensory bag, fixed at its margins to the ciliary processes by the suspensory ligament. This can be varied in length, and the lens consequently made more convex, by the action of the ciliary muscle, which is closely associated with the sclerocorneal margin (Fig. 157). This mechanism ensures that the lens can be accommodated to both near and distant objects—the property of accommodation mentioned above.

5. *The Chambers of the Eye.*—In front of the lens and behind the cornea is a small space filled with a fluid called aqueous humour, and known as the anterior chamber. Behind the iris is another chamber, called the posterior chamber. A third large chamber, the hollow space of the globe, contains the clear jelly of the vitreous humour, enclosed by a thin membrane, the hyaloid membrane. Since there are not any blood vessels crossing the vitreous, it depends for its fluid supply upon the exudations from the retinal vessels. It has an important function—that of keeping the globe in shape and preventing obstruction to light rays.

Appendages of the Eye.—1. *Eyelids.*—The muscles of these structures are described on pp. 106–107. Each eyelid consists of a semicartilaginous plate covered by skin on the outside and lined by a membrane called the conjunctiva on the inside (see below). The upper eyelid moves more freely than the lower and is also larger; it is the main factor in the opening and closing of the eye. The edges of the eyelids are furnished with eyelashes, which are protective against both dust and light. The space between the eyelids is known as the palpebral fissure. The eyelids contain vessels, nerves, glands and areolar tissue, but no fat.

2. *Eyebrows.*—These lie over the supraorbital arches and vary in shape and size according to the nature of the individual. They are used chiefly in expression, being operated mainly by the corrugator muscles.

3. *The Conjunctiva.*—This is a vascular, very sensitive and protective mucous membrane lining the eyelids and reflected on

to the eyeballs (Fig. 157). The portion on the lids is called the palpebral conjunctiva whereas that on the eyeball is known as the bulbar conjunctiva.

4. *Lacrimal Apparatus.*—Tears are more than the effluences of emotional states; they are the lubricants of the eye socket, and ensure that the eye is constantly bathed in a salty fluid, which not only nourishes the tissues but also acts as a mechanical cleanser. The lacrimal gland secretes the tears; it lies in the lacrimal fossa of the frontal bone, at the lateral and upper part of the orbit (Fig. 159). Small ducts pour out the lacrimal fluid over the upper surface of the eyeball. The action of the fluid is assisted by the regular blinking of the eyelids, which passes the tears over the eyeball to the medial canthus; there it collects, taking with it anything foreign to the eye. Here it will be noted there is a small punctate opening on each lid; these 2 pores lead into the nasal duct after entering an antechamber called the lacrimal sac. The nose is thus the drainage system of the eye, and this explains why vigorous blowing of the nose prevents weeping, since the drainage is accelerated.

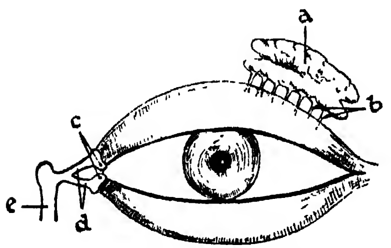


FIG. 159.—THE LEFT LACRIMAL APPARATUS.

a, Lacrimal gland. *b*, Ducts. *c*, Puncta lacrimalia. *d*, Lacrimal ducts. *e*, Duct leading to nose.

5. *Protection of the Eyeball.*—The eyeball is saved from injury, concussion or undue pressure by loosely packed fat and connective tissue, which act as padding chiefly behind the eyeball.

Physiology of the Eye: Optics.—We can now briefly outline the work done by the eye. No better example of a camera could be found, and if the principles of photography are understood by the student, the science of optics becomes comparatively simple. The whole principle is the convergence of rays of light so that these are focused on the retina and their stimuli registered by the retinal cells before being transmitted to the brain as light impulses. It is clear that the central window system—cornea, lens with its iris and the clear aqueous and vitreous humours—constitutes an ideal medium for the passage of light. The property of the lens in accommodating itself to various conditions allows the bending of the rays until they are focused on the macula lutea. The dark chamber filled with vitreous humour is ideal for the registering of the impression on the retinal cells, the chief focus point being the yellow spot. The image is

inverted here, but this is rectified by the retinal cells, and the sensation travels by the optic tracts to the occipital lobe, where appreciation of light impressions is translated into the sense of sight. Long sight, short sight and astigmatism are discussed in another part of this work (Section IX, Chapter 9); they are the result of abnormalities in the curvature of the eyeball. Colour blindness is an inability to distinguish between red and green; it is a sign of certain diseases, which are also dealt with later on in these volumes.

The Ear

The ear serves 2 purposes. It acts as the receptor of sound waves and it contains the organ of body equilibrium. It is divided into 3 chief parts—the outer ear, the middle ear and the internal ear.

The Outer Ear.—The external ear, or pinna, consists of the auricle and the opening of the auditory canal, which passes inwards. The pinna is like a small cup, its funnel-shaped outline assisting in the collection of sound waves. Structurally it is made up of a basis of cartilage with a few small muscles covered over by skin. The redness of the ears is due to the blood shining through the thin skin. The external auditory meatus is the technical name of the opening of the auditory canal, which runs inwards for a little over an inch until it reaches the drum of the ear. For the first ⅓ of its path the canal has a cartilaginous wall; after that it lies in the temporal bone (see p. 34). It is lined with skin, the hairs of which keep out foreign particles, while the glands secrete, instead of sweat, cerumen, the lubricating wax of the ear, familiar to everybody. The various parts of the external ear are shown in the diagram (Fig. 160).

The Middle Ear.—This portion is also known as the tympanic cavity. It is roughly cubical and is separated from the auditory canal by the drum of the ear, or tympanic membrane. It lies in the petrous portion of the temporal bone. The best way to study this chamber is to imagine that we have removed the ear drum. We now look right into the middle ear, and see that it contains 3 small bones which are linked together to make a chain across the cavity. Their names are, in order, the malleus, or hammer, the incus, or anvil, and the stapes, or stirrup. The handle of the malleus is fixed to the inner side of the tympanic membrane, and thus ensures that vibrations of the ear drum are transmitted along the chain. Two muscles are usually present in the middle ear—the tensor tympani, which, attached to the handle of the malleus, keeps up the tension of the drum, and the stapedius, acting on the stirrup. The walls of the cavity are lined with mucous membrane and enclose an

air space, which receives its supply from the pharyngo-tympanic (Eustachian) tube, a canal connecting the nasopharynx with the middle ear, just over one inch in length, and having its orifice at the lower part of the anterior wall. Its opening at the naso-pharynx is patent only during swallowing, and catarrh of the tube commonly occurs, causing a dull, "stuffy" sensation in the middle ear, with partial deafness. On the medial wall of the cavity are 2 openings, one circular, through which we can see the cochlea, and one oval, the fenestra ovalis, both covered by

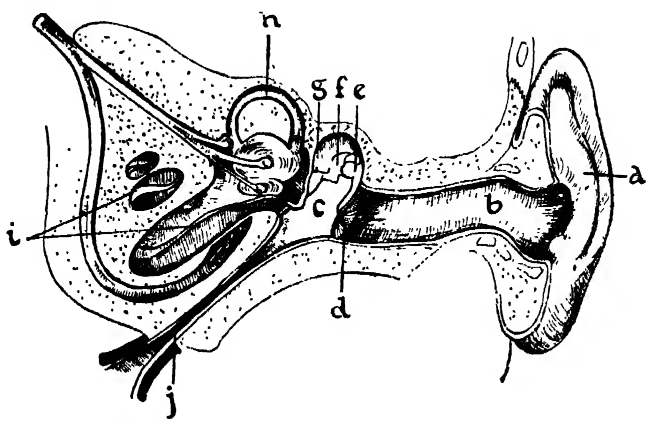


Fig. 160.—Section through the Left Ear.

a, Auricula. *b*, External acoustic meatus. *c*, Tympanic cavity. *d*, Tympanic membrane. *e*, Malleus. *f*, Incus. *g*, Stapes. *h*, Semi-circular canal. *i*, Osseous labyrinth. *j*, Pharyngo-tympanic tube.

membrane. In the latter is the footpiece of the stapes, passing on the sound vibrations. The posterior wall shows an opening, communicating with the important mastoid cells of the temporal bone and known as the aditus ad antrum. Mastoid cells often become infected in middle ear disease.

The Tympanic Membrane.—Possibly the most important member of the middle ear is the drum, or tympanic membrane. This appears as a pearly grey, somewhat concave partition when we examine it by special illumination. The handle of the malleus shines through, giving a ridge effect across the drum, as seen on examination. It is the sensitive, parchment-like tympanum which is the first filter in the system of sound transference.

The Internal Ear.—The contents of the internal ear have been well named the labyrinth. There is no more intricate or more delicate cavity in the body. The bony excavation from

the petrous temporal bone is called the osseous labyrinth; it surrounds a membranous chamber called the membranous labyrinth. Outside the latter is fluid known as perilymph, while inside is a similar substance, endolymph. The first portion of the osseous labyrinth is the vestibule, the entrance to which is the fenestra ovalis. In its cavity lies the membranous labyrinth, while in front is the cochlea and behind the semicircular canals, reached through 5 openings. The second portion is the mass of the semicircular canals. Three in number, these lie in different planes—superior, posterior and horizontal—so that each canal is at right angles to the other. There is a swelling at the vestibular junction called the ampulla (Fig. 160). The nerve supply to this area is very important; it is a branch of cranial nerve VIII known as the vestibular nerve, the filaments of which reach the cerebellum and apparently assist that organ in its work of balancing the body. The slight movements in the endolymph originate sensations which define our position. Air sickness, sea sickness and the giddiness of rotation of the body are all evidences of the disturbance of these canals. The cochlea resembles the shell of a snail. Spiral coils twist round a centre of bone called the modiolus. Internally the cochlea is divided into 3 compartments, and communicates with the middle ear by the fenestra rotunda, which is closed by membrane. The cochlea is the site of the auditory cells, collectively known as the organ of Corti. This consists of several rows of cells provided with cilia, which wave like fine hairs in the endolymph. By this means we can appreciate the various qualities of sound, and the sensations are transferred to the auditory centre in the brain by cranial nerve VIII.

Physiology of Hearing.—To sum up our observations, we must trace the journey made by sound from the outer air to the brain. The fundamental of any sound is a certain number of vibrations made by a body, and our consciousness appreciates noise or music according to the regularity of the impressions made. The index of sound is its " frequency " per second. In normal conditions we are constantly dealing with frequencies which vary between 50 and 4,000 vibrations per second, but it is possible to register 10 times the latter. Sound travels very fast but is affected by air currents and temperature. In a perfectly still atmosphere at a temperature of 60° F., the rate is 375 yards per second. All these vibrations are picked up by the auricle and passed down the auditory canal, where so to speak they beat the drum of the ear, which in turn passes its vibrations through the 3 ossicles to the fenestra ovalis, a second drúm. The perilymph is agitated, this affects the endolymph until finally the hairs of the organ of Corti are stimulated; then the afferent tract is followed to the temporal region of the cortex.

The Sense of Smell

The osseous and muscular structure of the nose have already been studied. All that remains to be done is to consider the sense of smell, which like taste is a protective function.

The Organ of Smell.—The first thing to be understood clearly is that the lower part of the nose is not the area which is concerned with smell. The air is warmed by passing over the nasal conchae, but not until the ethmoid bone is reached do we find that smell is appreciated. This is due to the fact that in human beings the sense of smell is a diminishing function, the ciliated receptor cells being limited to an area above the superior nasal concha and below the cribriform plate of the ethmoid. Even this part is difficult to reach by the inspired air, and we know that often to get the fullest measure of the scent of a substance we have to make the maximum effort of sniffing.

Gases are more quickly perceived by the smell organ because they are lighter and rise easily. Ordinarily, the small particles of the substance giving off an odour are the means of producing a smell, since by strong suction they are brought into contact with the sensitive epithelium and irritate the hairs. As we all know, there are certain smells which are so unpleasant that they cause nausea—probably a protective reaction on the part of the stomach.

Physiology of Smell.—The olfactory nerve bulbs, the terminations of cranial nerve I, lie on either side of the crista galli on the cribriform plate of the ethmoid bone. They send numerous filaments through to the mucous membrane, and by this pathway the stimuli are transferred to the cortex. Apparently the novelty of a smell wears off quickly because we frequently find that an atmosphere may have distinctly bad odour to a newcomer, while those in it are unaware of anything unusual.

It is well known that when there is catarrh of the nose, as in a cold in the head, the sense of smell is lost or diminished. This is due to swelling of the mucous membrane in the upper nasal cavities and interference with the ethmoidal passages.

Taste

Apart from its work in producing speech and in transferring food from the mouth to the pharynx, the tongue is the organ of taste. The muscles have been studied on pp. 112 and 197, and the physiology of swallowing on pp. 217–218; all that is now left for consideration is a brief description of the mucous membrane of the tongue. This covering varies in different parts of the organ.

Underneath it is glistening, smooth and very similar to the mucous membrane of the rest of the mouth. On the upper surface however and especially at the back of the tongue, the mucous membrane is very coarse, owing to the presence of certain papillae, which are very distinctly outlined by white fur e.g. after dietetic indiscretions. The diagram (Fig. 161) illustrates the distribution of these papillae, the types of which are 3 in number.

1. **Circumvallate Papillae.**—These form a V-shaped group of from 9 to 12 papillae, the tip of the angle almost reaching the foramen caecum, a depression situated at the base of the tongue (Fig. 161). The name is descriptive of the type of papilla; it resembles a castle with a rampart and moat. The taste buds are situated on the surface of the rampart.

2. **Fungiform Papillae.**—The fungiform papillae are mushroom-shaped and are situated on the tip, at the sides and on the posterior part of the upper surface. They are deep red and contain taste buds.

3. **Filiform Papillae.**—These form a field over most of the upper surface of the tongue but especially in the central part. They are cone-shaped and thread-like, hence their name.

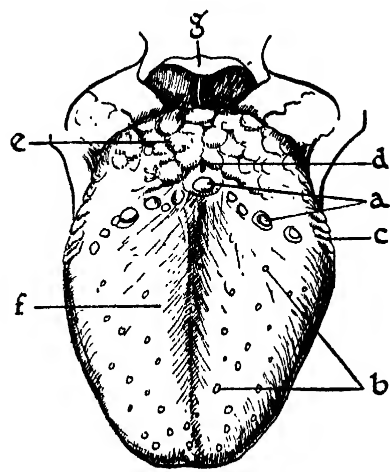


FIG. 161.—TONGUE AND TASTE BUDS.

a, Papillae circumvallatae. *b*, Papillae fungiformes. *c*, Folia linguae. *d*, Foramen caecum. *e*, Pharyngeal part of tongue. *f*, Oral part of tongue. *g*, Epiglottis.

The Taste Buds.—The sensory endings of taste are the taste buds, situated chiefly in the circumvallate and fungiform papillae (shown above). The filiform papillae are partly taste organs and partly touch organs. In addition to the taste buds on the tongue, there are also some scattered taste areas at the back of the palate. The 3 nerves concerned with taste are cranial nerve V, which is the sensory nerve to the anterior ⅔ of the tongue; the chorda tympani, a branch of cranial nerve VII, which supplies the same area but which is only a taste branch; and cranial nerve IX (glossopharyngeal), supplying the region of the circumvallate papillae and the posterior ⅓ of the tongue.

How Taste is Perceived.—Owing to the close association between smell and taste, it is difficult to say how much one influences the other. The same may be said of touch and sight; in this matter all the senses seem to work together. We can distinguish 4 elementary taste sensations—sweet, salt, bitter and sour, but in addition to this there are hundreds of complex flavours, depending upon mixtures of food.

Further, there are certain specialized parts of the tongue which seem to deal with particular types of taste sensation. Thus the tip of the tongue primarily deals with sweetness or saltiness; acids are recognized best at the edges; the tang of bitterness is perceived at the back.

Finally, in order to be fully appreciated, taste depends upon substances in solution for its full value. There may be a chemical reason for this, since the mucous membrane covering the papillae must be permeated before the taste buds receive their full stimulus from the substance in solution.

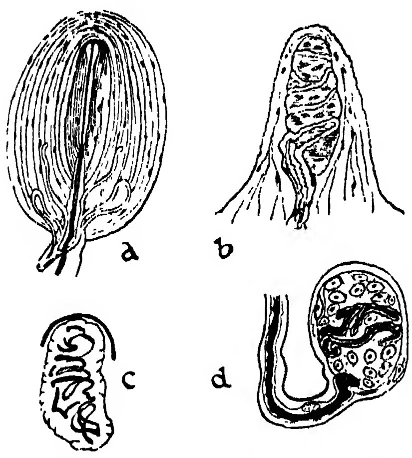


Fig. 162.—Types of Nerve Endings in Skin

a, Lamellated corpuscle. *b*, Papilla of the hand. *c*, Tactile corpuscle. *d*, Bulbous corpuscle.

Touch Sensation

In dealing with the skin, we found that it was covered with sensory nerve endings of all types, so that it was made possible to experience several types of sensation—pain, cold, heat, pressure and touch proper. The sensory spots specialize in specific types of sensation, but they are placed so closely together that it is often a mixed sensation which is produced. The sense of position, of weight and of pressure is transmitted from the muscles and joints, so that the finer endings on the skin are not used. In investigating touch we deal with two sensations viz. epicritic sensations, which refer to the nature, distribution and quality of light touch, and protopathic sensations, referring to deep pressure and pain.

Localization of touch varies according to the region. For instance it is possible to be very accurate in indicating the point

of contact of a pin with the tip of the finger; but when the back is under test, mistakes of 2 inches are frequent. Localization is said to be perfect or imperfect. Two things influence this: 1. distance apart of the end bulbs; 2. thickness of the epidermis.

CHAPTER 27

THE REPRODUCTIVE SYSTEM

FEMALE EXTERNAL ORGANS. THE MONS PUBIS. LABIA MAJORA. LABIA MINORA. THE CLITORIS. THE VESTIBULE. BULBI VESTIBULI. THE VAGINAL OPENING. THE HYMEN. THE FOURCHETTE. THE VAGINA. THE UTERUS. LIGAMENTS OF THE UTERUS. THE OVARIES. GRAAFIAN FOLLICLES. THE UTERINE TUBES. THE MAMMARY GLANDS. THE MALE REPRODUCTIVE ORGANS. THE URETHRA. THE PROSTATE GLAND. THE PENIS. THE TESTES. THE EPIDIDYMIS. THE VAS DEFERENS. THE SPERMATIC CORD. THE SEMINAL VESICLES. THE PHYSIOLOGY OF REPRODUCTION. MENSTRUATION. SEXUAL GLAND EXTRACTS.

THE reproductive system consists of the external and internal organs of generation and the mammary glands in the female, and the external and internal organs of generation in the male. Matters are simplified considerably when it is understood at the outset that the generative organs of both sexes are developed from the same source, and that however different the parts may appear on the surface they are modifications of a common pattern.

Female External Organs

Collectively the external generative organs in the female are known as the vulva (Fig. 163), and consist of the following structures.

The Mons Pubis.—This is a fatty mound, covered with connective and skin tissues, situated over the symphysis pubis; it is covered with hair after puberty.

Labia Majora.—These are the outer lips of the entrance to the reproductive canal. They lie below the vulva, stretching backwards for about 3 inches, and consist of smooth muscle, fat and skin. They have an ample blood and nerve supply.

Labia Minora.—Within the labia majora and attached to their upper margin are the labia minora, which hang down like

small curtains containing sebaceous follicles on their inner aspects. They are also known as the nymphae.

The Clitoris.—In structure and action, this part is the representative of the penis of the male, having an external sensitive glans which appears at the anterior angle of the labia minora. It contains erectile tissue.

The Vestibule.—Immediately below the glans clitoridis is a triangular space, bounded laterally by the labia minora and

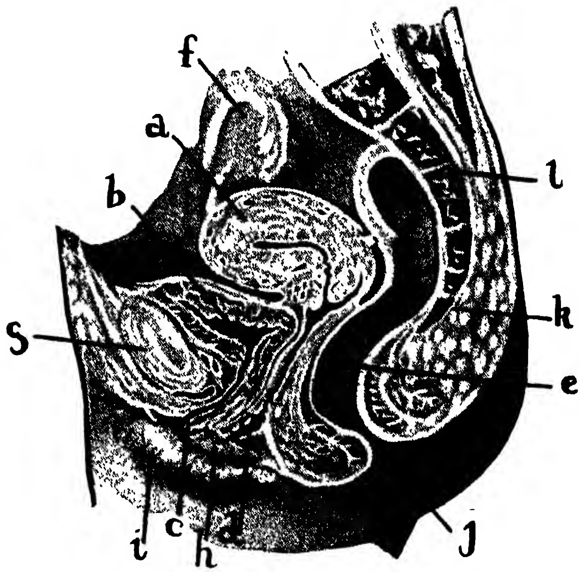


FIG. 163.—LONGITUDINAL SECTION OF FEMALE PELVIS.

a, Uterus. *b*, Bladder. *c*, Urethra. *d*, Vagina. *e*, Rectum. *f*, Colon. *g*, Symphysis pubis. *h*, Labium minus. *i*, Labium majus. *j*, Anal canal. *k*, Coccyx. *l*, Sacrum.

posteriorly by the opening into the vagina. This is known as the vestibule; it is occupied chiefly by the orifice of the urethra.

Bulbi Vestibuli.—These are two very vascular, erectile, oblong structures lying one on each side of the vestibule. A similar structure, the pars intermedia, lies immediately below the glans clitoridis.

The Vaginal Opening.—The entrance to the vagina is an opening about the size of a halfpenny, situated within the

labial folds and just behind the urethral outlet. In the virgin state, the opening is partially covered by a thin vascular membrane, the hymen. On either side of the vaginal orifice are the greater vestibular glands (glands of Bartholin) secreting their fluid on the inner surface of the labia minora. The vagina itself is partially closed by the bulbospongiosus muscle.

The Hymen.—This curtain may be like a ring or a crescent. After first sexual intercourse, the membrane is ruptured and the tags of tissue form small papules on the rim of the vaginal orifice; these are called carunculae myrtiformes.

The Fourchette.—A loose U-shaped fold of skin at the anterior edge of the perineum forms in its concavity a small depression behind the vaginal orifice, and is known as the fossa navicularis or fourchette.

Female Internal Organs

The Vagina.—The vagina is a slightly curved muscular canal lying between the rectum and bladder and reaching up as far as the neck of the womb. It is about 3 inches long, and normally its walls are in contact. The anterior wall is slightly shorter than the posterior wall and as the end of the womb dips into the top of the vaginal tube, it makes two small pockets anteriorly and posteriorly, called respectively the anterior and posterior fornix (Fig. 163). A finger placed in the posterior fornix should touch the base of the recto-uterine pouch (formerly termed the recto-vaginal pouch of Douglas). The structure of the vagina consists of a muscular coat, a layer of erectile tissue and an internal coat of squamous epithelium, amply supplied with mucous follicles. There are not any glands in this region. The lining is thrown into numerous rugae, which are horizontal folds keeping the shape of the tube intact. The blood supply is by various branches of the hypogastric arteries. The nerves spring from the vaginal plexus and the pudendal nerve.

The Uterus.—The uterus or womb is the centre of development of the unborn child. It is a very powerfully constructed, muscular organ, in shape and size like a pear, with the point jutting into the vagina (Fig. 163).

The uterus is roughly 3 inches long, 2 inches broad and 1 inch thick. It forms an angle with the vagina; its broad end, or fundus, points forwards. In front is the bladder and behind the rectum. It is partially covered with peritoneum. Internally there is a slight cavity, lined with specially thick mucous endometrium, about $\frac{1}{8}$ inch thick. The uterine tubes open into the fundus, one on either side. A vertical section of the uterus would show the structure illustrated in Fig. 163. The uterus is

seen to be divided into 3 chief portions—fundus, body and cervix. The walls are very thick ($\frac{1}{4}$ inch to $\frac{5}{8}$ inch), and the central canal varies in its lumen. At its termination in the vagina the small punctate opening of the uterus is called the external os. From this a small canal runs up to the main canal, which it enters at the internal os. The inner lining of this cervical canal is arranged in folds so that it resembles a feather or a tree. These are known as the arbor vitae. The muscles of the uterus are made up of 3 coats of unstriped muscle. The inner lining consists of ciliated columnar epithelium containing numerous glands, especially in the cervical region. The blood supply to the uterus is by the uterine and ovarian arteries. The nerve supply is from the hypogastric plexus and the sacral nerves (see pp. 266, 267, 271).

Ligaments of the Uterus.—An organ like the womb must obviously be fixed down by muscular structures, and no less than 8 ligaments are described. The 2 round ligaments are fibromuscular cords, like the guy ropes of a tent, running from the fundus on each side, downwards and outwards to the internal abdominal ring, where they are fixed. Each cord is 4–5 inches long. Otherwise the uterus is covered by a sheet of peritoneum which forms the following ligaments.

1. The anterior ligament, passing between uterus and bladder;
2. The posterior ligament, forming the recto-uterine pouch;
3. The sacro-uterine ligaments;
4. The broad ligaments—the largest and most important; these pass like a partition on either side of the uterus to the lateral pelvic walls. They are formed by a double fold of peritoneum which encloses the uterine tubes, round ligaments in part, ovaries, blood vessels, nerves and fibromuscular connective tissue.

The Ovaries.—At the lateral aspect of the broad ligament, on either side, are two egg-shaped organs, the ovaries. They lie immediately below the uterine tubes (Plate XVII). They are pinkish grey, and when divided are shown to contain a vascular stroma, supporting the Graafian follicles in various stages of activity.

Graafian Follicles.—These contain the ova, immersed in fluid. They have an external fibrovascular capsule, and internally, a lining membrane called the membrana granulosa, which shows a heaped-up mound of cells to which the ovum is fixed. After the discharge of an ovum, these bodies become puckered and yellow. The Graafian follicle then becomes the corpus luteum; later on in life, these bodies turn pale and degenerate.

Function of the Ovaries.—Apart from the production of ova (see also p. 294), the ovaries are now known to be responsible for the generation of internal secretions, which are essential for

the proper development and functioning of the female reproductive system; thus the ovaries are very important ductless glands producing endocrines. The internal secretions are 1. Oestrogen, the secretion of the Graafian follicle, which is an important factor in the development of the new mucosa of the uterus after menstruation and many other phenomena connected with the menstrual cycle; 2. Progesterone, the secretion of the corpus luteum. The latter hormone is active in pregnancy and is said to inhibit menstruation and ovulation during pregnancy.

The Uterine Tubes.—These tubes extend from the fundus of the uterus to the ovaries; they were formerly known as the Fallopian tubes. They are about 4 inches long, narrow at the uterine end, but widened out into ampullary ends with fimbriated margins partly attached to the ovary (Plate XVII). The external opening is into the peritoneal cavity. The nerve supply, as in the ovaries, is from the hypogastric and ovarian plexus. Between the ovary and uterine tube is a small organ, the parovarium, a group of tubules situated in the broad ligament, remnants of a foetal structure, the Wolffian body. The blood supply of this region is by the ovarian artery.

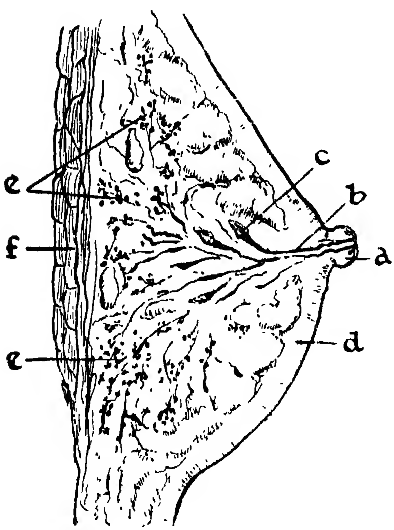


FIG. 164.—SECTION THROUGH THE MAMMARY GLAND.

a, Nipple. *b*, Lactiferous tubule. *c*, Ampulla. *d*, Skin. *e*, Peripheral processes *f*, Pectoralis major muscle.

The Mammary Glands

The mammae, or breasts, are two hemispherical glands situated on either side of the chest. They vary considerably in individuals, but as a general rule occupy the space enclosed by the 3rd rib, 7th rib, lateral sternal margin and anterior boundary of the axilla. They are covered by superficial fascia. The organs are surmounted by the nipple, which is dark and rudimentary with a ring of delicate pink skin round it in virgins—the areola; under the latter lie small special-

CONTENTS OF THE FEMALE PELVIS ANTEROSUPERIOR ASPECT.

a, Uterus. *b*, Bladder. *c*, Sigmoid colon. *d*, Ovary. *e*, Ligament of ovary. *f*. Round ligament of uterus. *g*, Sacral promontory. *h*, Ureters. *i*, Sacrogenital fold. *j*, Descending colon. *k*, Uterine tube.

ized sebaceous glands—the areolar glands (Montgomery's tubercles) which during pregnancy become enlarged and prominent in a deeply pigmented ring. The pigmentation fades after the child is born, but the areola rarely returns to its original pink coloration. These glands are undeveloped in the male unless some abnormality exists. The breasts develop at puberty and become full and of maximum activity during pregnancy, and when the mother is feeding her child at the breast; in old age they atrophy. They vary in size and shape according to race, heredity, circumstance and individual peculiarity.

Internally, the breast shows lobes of gland tissue, with their ducts, which are supported by fatty and areolar tissue, the whole being invested by a thin fibrous capsule. From every lobe (there are about 15) a lactiferous duct runs to the areolar region, where the milk collects in ampullae before it is passed through the nipple in separate openings. Each lobe consists of several lobules with their small ducts acting as tributaries to the lactiferous ducts, while the lobules are made up of alveoli, the real manufactories of the milk (Fig. 164). There is an abundant lymphatic supply, chiefly passing to the axillary glands. An ample blood supply is derived from the axillary, intercostal and internal mammary arteries; the nerves are branches of the intercostals.

The Male Reproductive Organs

The first part of the male generative system is associated with the urinary system; in micturition and in ejaculation of seminal fluid, the same canal—the urethra—is used.

The Urethra.—This is the canal which leads from the base of the bladder to the end of the penis. It is about 8 inches long. Immediately after leaving the bladder, it passes through an investing structure about the size of a chestnut and known as the prostate gland. The prostatic part of the urethra shows openings for the prostatic ducts, and an obscure elevation of the mucous membrane, over ½ inch long, said to contain muscle and erectile tissue; just below it is the uterus masculinus, which is part of the substance of the prostate gland. Here also open the ejaculatory ducts. The second part of the urethra is the thin membranous portion situated in the perineum; the canal turns here at an angle of about 90° and enters the penis. It contains the orifices of the bulbo-urethral glands. In the penis, the urethra is lubricated by numerous mucous glands; it terminates in the meatus, a vertical opening about ¼ inch long situated between two minute labia.

(In the female the urethra is only 1½ inches long and is unconnected with the reproductive system It is a simple canal, about ¼ inch wide and easily dilated.)

The Prostate Gland.—This gland is partly muscle and partly gland tissue; it surrounds the neck of the bladder and consists of two lateral lobes and one central lobe. It is enveloped by a capsule of fibrous tissue which dips into the follicular pouches of gland tissue. The ducts, 18–20 in number, open into the prostatic part of the urethra. The bulbo-urethral glands are two pealike bodies situated just below the prostate gland, their ducts opening as described above. The secretion of the prostate gland mixes with the seminal fluid. A great amount of investigation has been made within the past few years regarding the functions of the prostate gland, and it is now regarded as being very sensitive to certain hormones. Experiments on animals have shown that the prostatic fluid contains enzymes.

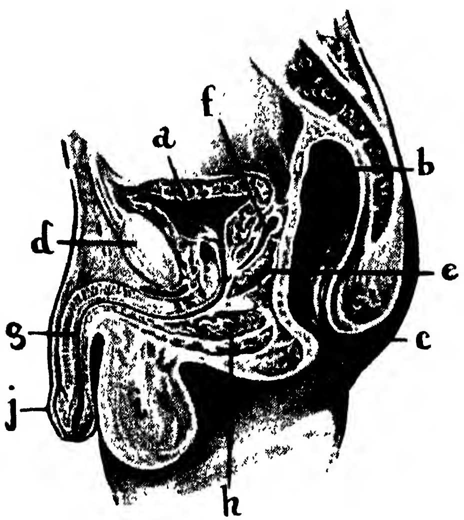


FIG. 165.—LONGITUDINAL SECTION OF MALE PELVIS

a, Bladder. *b*, Rectum. *c*, Anal canal. *d*, Symphysis pubis. *e*, Prostate. *f*, Ejaculatory duct. *g*, Urethra. *h*, Bulb of urethra. *i*, Scrotum. *j*, Penis

The Penis.—The penis consists of 3 cylindrical columns, each surrounded by fibrous sheaths sending bands to support the erectile tissue contained within (see Fig. 165). The cylindrical compartments thus become divided up into spaces like a honeycomb, capable of great distension by venous blood supplied to the penis when there is an erection stimulus. The two largest columns lie side by side in front, and are known as the corpora cavernosa, while the smaller one lies behind and between them, and is known as the corpus spongiosum. The former are close together for $\frac{3}{4}$ of the length of the penis; their posterior $\frac{1}{4}$ runs on each side to form the crura with the pelvic bones. As shown in the section (Fig. 165), the urethra runs in the corpus spongiosum, while the vessels and nerves run in a groove above the corpora cavernosa. At the termination of the penis, the corpus spongiosum expands into the glans penis, a

heart-shaped portion covering the corpora cavernosa, and having a rounded border called the corona, with a deep groove beneath. The glans penis is covered with epithelium, and over it is a hood of skin, variable in length, called the prepuce, or foreskin. This is connected by a tag of mucous membrane with the median *raphé* of the glans.

The Testes.—These are the representatives of the ovaries. They are developed in the abdomen; but ultimately descend to the scrotum or bag which lies below the penis, by way of the inguinal canal. The left testicle usually lies a little lower than the right. Each testis is an oval body, weighing about ¾ oz. and measuring roughly 1 inch by 1½ inches. It is suspended by the spermatic cord. The function of the testis is to manufacture spermatozoa, the active male reproductive elements. It has several fascial coverings derived from the abdomen during its descent.

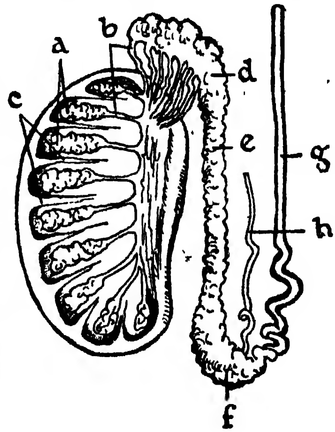


Fig. 166.—Section through the Testis.

a, Convoluted tubules. *b*, Straight and efferent ductules. *c*, Septa. *d*, Head of the epididymis. *e*, Body of epididymis. *f*, Tail of epididymis. *g*, Vas deferens. *h*, Aberrant duct.

Stripped of these coverings, the testis shows a tunica vaginalis, which is the external serous covering, a fibrous middle coat, and a vascular inner coat. The middle coat sends in bands of tissue, dividing the interior of the testicle into compartments which are lined by the vascular coat. The testis is thus divided into about 300 lobules, each one occupying a space, and made up of from 1–3 convoluted tubes—the seminiferous tubules. Ultimately these convoluted tubules become straight and unite to form about 24 ducts, the vasa recta, which in turn open into the rete testis, a network of tubes emptying into the vasa efferentia. These number about 15, and open into conical masses forming the head of the epididymis or globus major (Fig. 166, which is a diagram only).

The Epididymis.—This lies along the posterior border of the testis, and is simply a very much convoluted tube, 20 feet long, but compressed into 1 inch of length. The globus major or head is formed as described above; a single tube replaces the vasa efferentia. The body is the tangled mass of tubing held lightly

together by areolar tissue. Its lower end is called the globus minor or tail.

The Vas Deferens.—The vas deferens is the continuation of the tube of the globus minor; it passes through the inguinal canal, and after crossing important intra-abdominal structures, it reaches the base of the prostate gland, where it joins the ejaculatory duct. The total length is 2 feet. It consists of an areolar, a muscular and a mucous coat.

The Spermatic Cord.—The spermatic cord can be felt as a firm cord passing down from the inguinal canals on either side to the testicles. It contains the vas deferens, various arteries, veins and nerves, and numerous coverings of fascia.

The Seminal Vesicles.—These are situated between the base of the bladder and the rectum, lateral to the vasa deferentia. They are lobulated pockets, about 2½ inches long. In addition to being reservoirs for semen, these vesicles form a secretion of their own. They end in a duct common to seminal vesicle and vas—the ejaculatory duct, which joins the urethra as described already.

The Physiology of Reproduction

Today the public wants to know everything about reproduction, but it is difficult to educate when certain functions are still under discussion. A brief but simple outline of the physiology of the generative organs may help nurses to understand more fully the searching problems presented to them by patients.

In the female, ova are produced and extruded from the Graafian follicles about 14 days after menstruation. Presumably a certain number of ova must be lost in the peritoneum, but several are caught by the fimbriated end of the uterine tube, where they may live for a period. In the male, spermatozoa are being constantly manufactured in the testes, passed along the vasa deferentia and finally stored in the seminal vesicles (see above).

Sexual intercourse normally is preceded by mutual desire for coitus, which should be a natural, healthy function like eating or drinking. The vaginal orifice becomes lubricated by the greater vestibular glands, a certain amount of cervical secretion descends, and the vaginal sphincters are relaxed. The penis of the male becomes erect, and is easily inserted into the vagina until the cervix uteri is reached. Here, it is doubtful if the os dilates, but in the movements of copulation undoubtedly two things occur: 1. the sensitive nerves on the glans penis are stimulated and gradually produce the orgasm or crisis, which ends by the liberation of the accumulated semen from the vesiculae seminales, and

its passage through the external meatus; 2. there is a simultaneous crisis in the female, which may possibly indicate a suction action on the part of the uterus. Whatever the reaction, the sexual act results in the deposition of about a dessertspoonful of seminal fluid round the cervix, and therefore of thousands of sperm cells, each with a tail which propels it up the cervical canal. Several must reach the upper part of the uterine tube eventually, for it is in this part that the ovum is met (not below) and one spermatozoan, only, pierces an ovum, starting a new life, the understanding of which belongs to the science of embryology. This is the true act of fertilization, the ovum with its particular spermatozoan descending to the upper part of the uterus and taking nearly a week for the journey. Once the two reach the uterine mucous membrane, pregnancy is in process and numerous other collateral changes occur, but normally from this period until the end of pregnancy, sexual intercourse is reproductively ineffective.

Menstruation.—Every 24–28 days the uterine lining is shed, the process being known as menstruation. When pregnancy occurs, menstruation stops, and while a mother is nursing her child it is usually in abeyance. The normal age-period for menstruation is 14 to 45. After the age of 45, a radical change occurs, with loss of many sexual functions and properties. The change is called the menopause and is accompanied by many symptoms depending a good deal on the sympathetic nervous system.

Sexual Gland Extracts.—Recent work has proved that in both sexes the absorption of certain important substances takes place from testis or ovary. These internal secretions, or hormones, have powers of maintaining the sexual characteristics, and are in association with the other ductless glands. Most of them have already been mentioned, but later on in this work, the subject of sex hormones again comes up for discussion at several places.

CHAPTER 28

REGIONAL AND SURFACE ANATOMY

REGIONAL ANATOMY. THE THORAX. CONTENTS OF THE THORAX. THE ABDOMEN. CONTENTS. THE PELVIS. CONTENTS. SURFACE ANATOMY. HEAD. NECK. THORAX. ABDOMEN. THE EXTREMITIES. IMPORTANT SPACES. THE AXILLA. THE ANTECUBITAL FOSSA. THE FEMORAL TRIANGLE. THE POPLITEAL SPACE.

A KNOWLEDGE of the anatomy of the body is not complete unless we know the relationship of the various organs. On account of this it is convenient to study the structures according to the region in which they are situated.

Regional Anatomy

The chief cavities of the body are the head, thorax, abdomen and pelvis. The head has already been fully described in various chapters.

The Thorax.—The cavity of the thorax, or chest, is formed by the thoracic part of the vertebral column behind, the 12 ribs and the sternum in front. It is somewhat like a barrel, the ribs representing the hoops.

The boundaries are the sternum with the costal cartilages in front; behind, the dorsal spine with its intervertebral discs, its ligaments and associated muscles; the sides, the ribs with the intercostal muscles filling up the spaces between them; below, the great domed mass of the diaphragm.

Contents of the Thorax.—The greatest space is occupied by the lungs, one on each side; these take the shape of the pyramidal casing of bone formed by one half of the thorax. The parietal pleura covers the inside of the chest wall. In the middle of the space, lying behind the sternum and partly beyond it to the left, is the heart in its pericardial sac; it is surrounded and partially overlapped by lung tissue. The great vessels of the chest lie above the heart, the aorta sweeping round in an arch from right to left and giving off its innominate, common carotid and subclavian branches, the pulmonary artery going to the lungs, and

the superior vena cava rising up on the right side to divide into the right and left innominate veins (see Plate VII).

Between the carotid arteries, as they pass up towards the neck, is seen the trachea, easily distinguished by its cartilaginous rings; if we follow it down, we find that it bifurcates at the level of the 4th dorsal vertebra into the right and left bronchus. Behind the trachea, but slightly overlapping it, is the gullet, which passes down the posterior wall to pierce the diaphragm. The thoracic duct—the great lymphatic channel—is also noticed; it tends to run from the middle of the column to the left side. Many glands are also visible, especially at the roots of the lungs and round the great tubes. The vagus nerve and the phrenic nerve can be traced descending on either side of the great vessels, while the sympathetic chain with various ganglia may be found passing over the heads of the ribs.

The mediastinum is the space left between the lungs, and occupied by the heart and most of the other members of the cavity. It is divided into four parts. The superior portion lies above the level of the pericardium, the anterior between the sternum and pericardium; the middle contains the heart, while the posterior lies behind the heart.

The Abdomen.—This is the largest cavity in the body, being bounded above by the diaphragm, below by the rim of the pelvis (which is a subsidiary cavity described below), in front by the abdominal muscles, at the sides by portions of the lower ribs, muscles and parts of the iliac bones, behind by the spine and the psoas and quadratus lumborum muscles.

Contents.—The stomach and small and large intestines; the liver, occupying the upper right corner; the gallbladder, lying below the liver; the pancreas, behind the stomach; the spleen, in the left upper corner; the omentum, usually with a good deal of fat in front, causing the anterior egg-like bulge of the abdomen; the kidneys and suprarenal bodies, lying embedded in fat on the back of the abdominal wall; the ureters, passing from the hilum of the kidney downwards and inwards to the base of the bladder; the abdominal aorta, inferior vena cava and thoracic duct, and numerous branches running to various organs; glands; nerves; lymphatic vessels.

The Pelvis.—This is the cup-shaped cavity formed by the pelvic bones. The brim of the pelvis is mapped out by drawing a line beginning at the promontory of the sacrum, along the ilio-pectineal line, to the crest of the os pubis, and tracing it back on the opposite side to the starting point. The floor of the pelvis is somewhat funnel-shaped, the levator ani and coccygei muscles forming the base. The posterior boundary is the sacrum and coccyx, together with their associated ligaments. At the front

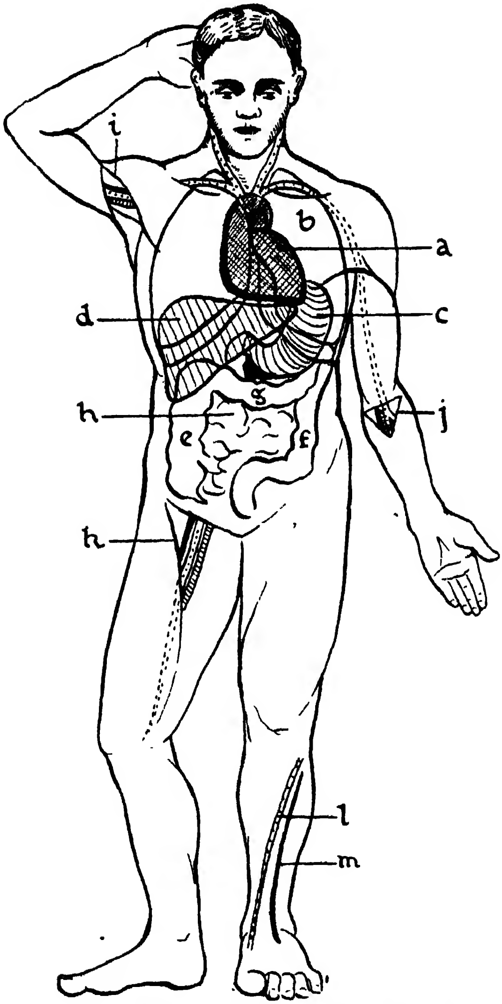


FIG. 167.—REGIONAL AND SURFACE ANATOMY (ANTERIOR).

a, Heart and pericardium, with great vessels of the neck.
b, Left lung.
c, Fundus of stomach.
d, Dome of liver.
e, Ascending colon.
f, Descending colon.
g, Transverse colon.
h, Small intestines.
i, The axilla.
j, The antecubital fossa.
k, The femoral triangle. The dotted line represents the continuation of the structures through the subsartorial canal.
l, Course of anterior tibial artery.
m, Course of musculo cutaneous nerve.

is the os pubis, while the lateral boundaries are the pubic and ischial bones and the obturator internus muscle.

Contents.—In the female the organs seen from before backwards are the bladder, fundus of uterus and rectum, all covered by a sheet of peritoneum. The recto-uterine pouch is a peritoneal pocket lying between the uterus and rectum. The pelvic colon is seen to the left of the upper part of the pelvis, coming down from the descending colon to meet the rectum. Many glands, vessels and nerves can also be observed.

Surface Anatomy

Surface anatomy is the geography of the external aspects of the body. By fixing various landmarks and joining definite points we can make maps on the skin of the structures underneath. This is very useful in surgery.

Head.—Prominent points on the head are the occipital protuberance behind and the nasion in front i.e. the frontonasal suture; by joining these points over the crown of the head, we map out the line of the superior sagittal sinus. The tip of the mastoid process is easily felt behind the ear, as also the angle of the mandible, temporomandibular joint and zygomatic bone. The parotid gland and the submaxillary gland, situated in front of the ear and below the mandibular angle respectively, can be felt on careful palpation. The superficial temporal artery can often be seen as a tortuous vessel running upwards to the temporal region just in front of the pinna. The facial artery is easily felt as it crosses the lower jaw, just in front of the anterior border of the masseter muscle.

Neck.—The sternomastoid muscle, running obliquely downwards, divides the neck into an anterior and a posterior triangle. Structures in the anterior triangle are the common carotid artery (which splits at the level of the thyroid into its 2 main branches), the internal jugular vein, the vagus nerve, the hypoglossal nerve and various muscles. Chains of lymphatic glands are found. In the posterior triangle, which is bounded behind by the trapezius and below by the clavicle, there is the brachial plexus, the subclavian artery and lymphatic glands.

Thorax.—Posteriorly the vertebra prominens, the inferior angle of the scapula and the line of the trapezius and deltoid muscles should be made out. Anteriorly the angle of Louis on the sternum marks the 2nd rib level. The apex beat of the heart is found in the 5th left costal interspace, just internal to the line passing vertically through the nipple. The upper border of the heart is about the level of the 3rd rib, the right border just beyond the right sternal margin (Fig. 167).

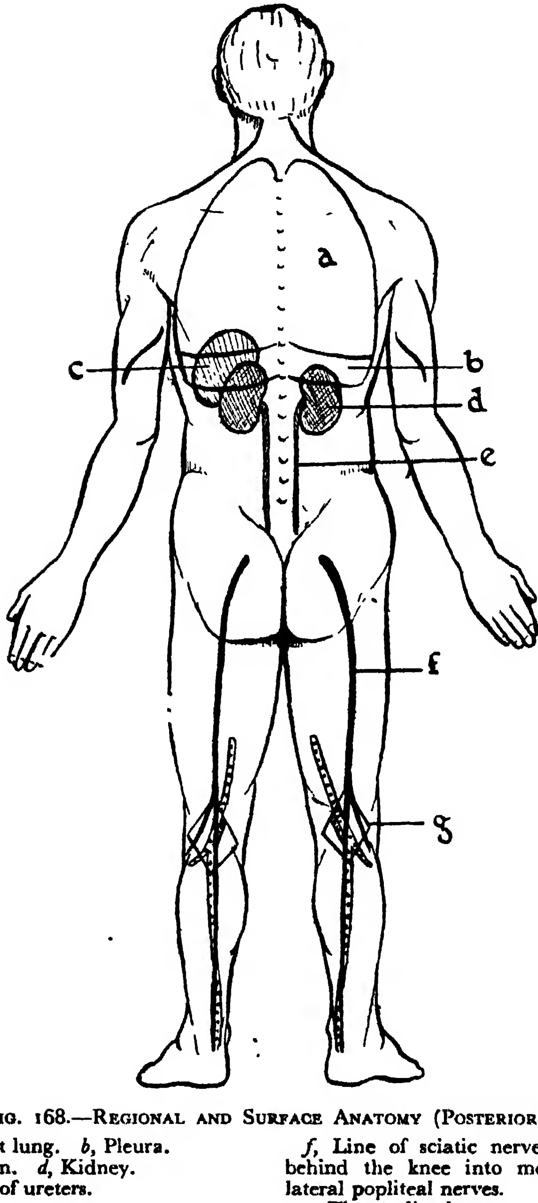


FIG. 168.—REGIONAL AND SURFACE ANATOMY (POSTERIOR).

a, Right lung. *b*, Pleura.
c. Spleen. *d*, Kidney.
e. Line of ureters.

f, Line of sciatic nerve dividing behind the knee into medial and lateral popliteal nerves.
g, The popliteal space.

Abdomen.—The abdomen is mapped out into 9 areas, as shown in the diagram; various structures may be found constantly in each square. The two vertical lines on either side meet the mid-point of an imaginary line drawn from the anterior superior spine of the ilium to the symphysis pubis, while the horizontal lines run across at the level of the tenth costal cartilage, and between two points 2 inches above the anterior superior spine i.e. through the tips of the crests of the ilium (Fig. 169).

One landmark important in appendicitis is called McBurney's point. It is found by drawing a line from the umbilicus to the anterior superior spine on the right side; take the middle point of this line; the appendix lies just laterally to it, and this is the spot of maximum tenderness in acute appendicitis.

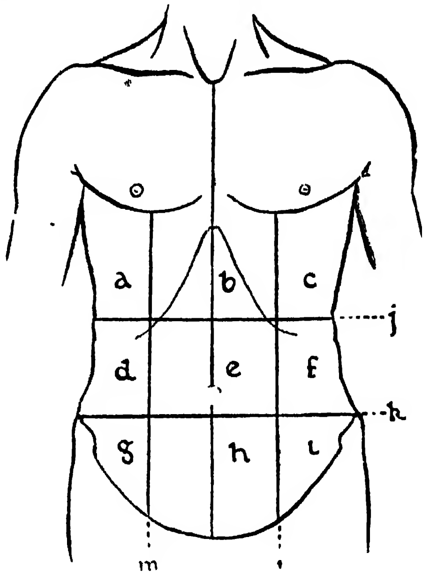


FIG. 169.—AREAS OF ABDOMEN.

a, Right hypochondriac region, containing liver. *b*, Epigastric region, containing liver and stomach. *c*, Left hypochondriac region, containing stomach and splenic flexure. *d* and *f*, Right and left lumbar regions containing parts of colon. *e*, Umbilical region. *g*, Right iliac region, containing caecum. *h*, Hypogastric region, containing bladder and upper part of rectum. *i*, Left iliac region, containing descending colon and sigmoid flexure. *j*, Transpyloric plane. *k*, Transtubercular plane. *l*, *m*, Left and right lateral planes.

The Extremities.—The surface anatomy of the main vessels is given in the next section, Fig. 174, therefore this is omitted here. On the arm we recognize the bony points of the olecranon behind the elbow, and at the sides the epicondyles. At the wrist, the bony ends of the radius and ulna are quite distinct. In the lower extremity, the greater trochanter can be felt at the outer and upper part of the thigh; Nélaton's line, drawn from the anterior superior spine to the tuberosity of the ischium, passes through the tip of the great trochanter, and through the hip joint. The line of the sciatic nerve may be mapped out by taking the middle of the lower fold of the buttock (i.e. the mid-point of a line drawn from

the tuberosity of the ischium and the greater trochanter) and dropping a perpendicular line to the foot. In front of the knee the patella can be moved freely. In the foot the prominences of the medial and lateral malleoli indicate the beginning of the tarsus; the navicular bone is palpable on the medial border of the foot, while on the lateral aspect is the tubercle of the 5th metatarsal bone.

Important Spaces

The Axilla.—Situated between the arm and the chest wall.

Boundaries.—Internally, chest wall; externally, humerus and muscles; posteriorly, teres major and muscles going to scapula; anteriorly, the pectorals.

Contents.—Axillary artery, axillary vein, brachial plexus, lymphatic vessels and glands (Fig. 167).

The Antecubital Fossa.—The bend of the elbow (Fig. 167).

Boundaries.—Above, bend of elbow; laterally, brachioradialis; medially, pronator teres; floor, brachialis.

Contents.—Brachial artery, median nerve, tendon of the biceps, veins.

The Femoral Triangle.—A space at the groin (Fig. 167).

Boundaries.—Above, inguinal ligament; laterally, sartorius muscle; medially, adductors of the thigh; floor, deep thigh muscles.

Contents.—Femoral artery, femoral vein, femoral nerve, lymphatic glands and vessels.

The Popliteal Space.—The region behind the knee. Diamond-shaped (Fig. 168).

Boundaries.—Above, the lateral and medial hamstring muscles; below, lateral and medial heads of gastrocnemius. Floor, back of knee joint.

Contents.—Popliteal artery; popliteal vein; medial and lateral popliteal nerves; lymphatic glands.

CHAPTER 29

SUMMARY OF ANATOMICAL TERMS

In the following pages, the terms used in the nomenclature of the Anatomical Society of Great Britain and Ireland are given in alphabetical order, and opposite them are their equivalents of the old terminology. It is hoped that nurses who may still be taught under the old rules will have no difficulty in finding out the appropriate terms of the new nomenclature, which is employed in this work, although the old names are sometimes also used.

Anatomical Society's Nomenclature	*Old Terminology*
Abductor pollicis longus.	Extensor ossis metacarpi pollicis.
Annular ligament of radius.	Orbicular ligament.
Anterior cutaneous nerve of neck.	Superficial cervical nerve.
Aqueduct of mid-brain.	Sylvian aqueduct.
Arcuate artery.	Metatarsal artery.
Arcuate line.	Semilunar fold of Douglas.
Atrium.	Auricle.
Auricle.	Auricular appendix.
Auricularis anterior.	Attrahens aurem.
Auricularis posterior.	Retrahens aurem.
Auricularis superior.	Attolens aurem.
Basilar sinus.	Transverse sinus.
Basis pedunculi.	Crusta.
Brachioradialis.	Supinator longus.
Bulbo-urethral glands.	Cowper's glands.
Calcaneum.	Os calcis.
Canal for chorda tympani.	Canal of Hugier.
Canal for facial nerve.	Aqueductus Fallopii.
Capitate bone of hand.	Os magnum.
Capitulum of humerus.	Capitellum.
Caudate lobe of liver.	Spigelian lobe.
Caudate process of liver.	Lobus caudatus.
Cavity of septum lucidum.	Fifth ventricle.
Central sulcus.	Fissure of Rolando.
Cervical root of accessory nerve.	Spinal root of spinal accessory.
Ciliary zonule.	Suspensory ligament of lens.
Circulus arteriosus.	Circle of Willis.
Circumflex scapular artery.	Dorsalis scapulae.
Clavipectoral fascia.	Costocoracoid membrane.
Coeliac ganglia and plexus.	Semilunar ganglion and solar plexus.

Anatomical Society's Nomenclature	*Old Terminology*
Profunda artery of tongue.	Ranine artery.
Profunda brachii artery.	Superior profunda.
Pudendal artery and nerve.	Pudic.
Pudendal canal.	Alcock's canal
Radial nerve.	Musculospiral nerve.
Radiate ligament.	Anterior costovertebral (stellate).
Rectal artery.	Haemorrhoidal.
Right and left flexures of colon.	Hepatic and splenic flexures.
Right and left gastric arteries.	Pyloric and coronary.
Sacrospinalis muscle.	Erector spinae.
Sacrospinous ligament.	Small sacrosciatic ligament.
Sacrotuberous ligament.	Great sacrosciatic ligament.
Semispinalis capitis.	Complexus.
Sensory root of facial nerve.	Nervus intermedius.
Sigmoid cavity of radius.	Ulnar notch of radius.
Soleal line.	Oblique line of tibia.
Spaces of iridocorneal angle.	Spaces of Fontana.
Sphenomandibular ligament.	Internal lateral ligament of jaw.
Sphenopalatine nerve.	Nasopalatine nerve.
Spherical recess of vestibule.	Fossa hemispherica.
Spinalis thoracis.	Spinalis dorsi.
Squamotympanic fissure.	Glaserian fissure.
Submandibular duct.	Wharton's duct.
Subsartorial canal.	Hunter's canal.
Sulcus cinguli.	Callosomarginal sulcus.
Superficial inguinal ring.	External abdominal ring.
Superior ganglion of glossopharyngeal.	Jugular ganglion.
Superior ganglion of vagus.	Ganglion of root.
Superior orbital fissure.	Sphenoidal fissure.
Supratrochlear artery.	Anastomotica magna of brachial artery.
Sural nerve.	External or short saphenous.
Talus.	Astragalus.
Tena chorioidea of third ventricle.	Velum interpositum.
Tendo calcaneus.	Tendo Achillis.
Testicular artery.	Spermatic artery.
Transverse folds of rectum.	Houston's valves.
Transverse sinus.	Lateral sinus.
Transversus thoracis.	Triangularis sterni.
Trigeminal ganglion.	Gasserian ganglion.
Triquetral bone of hand.	Cuneiform.
Trochlear notch of ulna.	Greater sigmoid cavity.
Ulnar collateral artery.	Inferior profunda.
Urethral crest.	Verumontanum.
Uterine tube.	Fallopian tube.
Vastus intermedius.	Crureus.
Venae hemiazygoi, superior and inferior.	Venae azygoi minores.
Vestibular fold.	False vocal cord.
Vocal fold.	True vocal cord.

SECTION II

FIRST AID

CHAPTER I

THE NATURE AND PRINCIPLES OF FIRST AID

GENERAL PRINCIPLES OF FIRST AID. THE ESSENTIAL QUALIFICATIONS OF FIRST AIDERS. TREATMENT BY FIRST AID METHODS. KNOWLEDGE OF ANATOMY AND PHYSIOLOGY.

First aid is a means to an end. It is a system of help in an emergency and at no time is it to be regarded as treatment of a permanent type. That it is needed is perfectly obvious from the statistics of road and street accidents, sudden catastrophes in the home and unexpected happenings in places far away from the doctor's surgery. One of the most important educational movements in Great Britain is the system of first aid classes held under the auspices of the St. John Ambulance Association, the British Red Cross Society, the St. Andrew's Ambulance Association, the London County Council, the London Fire Brigade and many other bodies. Certificates in first aid are granted after examination, and vouchers and medallions are awarded later for greater proficiency. There is an ever increasing leaven of qualified first aid men and women in the country, and collectively and individually they are doing an amount of work the value of which is impossible to assess. In industry, on the railways, in the factory and on the farm, these "first aiders" are proving their importance to economy and to health. Prompt application of the remedy at the specific moment may save life and money.

In order to be able to apply the remedy promptly, however, instruction must be given in the principles of first aid. To be able to find out the true nature of the injury (diagnosis) and to decide about the application of the remedy (treatment) are the two things which concern the first aid student. In preparing a scheme of education for lay men and women, the various bodies have carefully sifted out the essentials, and generally extracted the basic and fundamental principles of the science, so that while first aid may often seem incomplete, it is sufficient to satisfy all the demands of the emergency and to tide the patient over

until he is put into the hands of a doctor. Everyone who goes in for the study of first aid is convinced, sooner or later, that he or she is not expected to do a doctor's work. It is an art which is really outside the ordinary run of medical practice and it demands a type of skill and ingenuity of different nature from that of the medical profession. Nurses, in studying this section, will no doubt understand that while first aid knowledge is to them essential in their education, it does not in any way infringe on the orthodox work of the hospital or nursing home. But first aid proficiency may come in handy to a nurse at any time, and not only will the following few chapters (which are admittedly insufficient to cover the whole standard course of first aid) be of use to her if she should be called out in an emergency, but they will also give her confidence in the knowledge that she is able to render the assistance necessary in the approved way. She will also be able to appreciate the point of view of the first aider whose cases may come under her care in the hospital.

General Principles of First Aid.—The knowledge required is definite, thorough and elementary. There is no question of encroachment on the doctor's province. All first aid experts are modest and simple in their understanding; they know that where their work ends that of the doctor begins. The following is a brief outline of the points which must be noted by those who mean to do their ambulance work efficiently.

1. *Method of approach.*—In all emergencies, no matter what the degree may be, it is essential that the first aider should have some definite and reliable plan of action. She should act quickly, but should aim at the avoidance of giving any impression of haste. She should train herself to assume a quiet, calm and efficient manner; she should not show any degree of excitement; her voice should be soft, well controlled and natural. A quiet and confident front engenders a feeling of security in the patient and may be an enormous asset in fortifying him against symptoms of shock and collapse.

2. *The person or persons to be treated.*—A rapid decision as to the relative seriousness of the cases in a major accident is essential. The position of the patient is very important. It must be decided whether he has assumed it by design or by accident.

3. *The degree of injury or illness.*—In assessing this, there is much to be learned from the history, the symptoms (what the patient complains of) and the signs (what is observed by the first aider himself).

History can be obtained from the patient, from his relatives or from passers-by. All examinations should be made with as little exposure as possible; it must be remembered that a conscious patient may be extremely sensitive to the situation in which he finds himself. If it should be necessary to remove

clothing for treatment and examination purposes, this should always be done with careful regard to delicacy and modesty. Symptoms usually point to pain, discomfort, dizziness, thirst and other unusual sensations. These two sources of information may provide the investigator with much knowledge of the circumstances of the case, but their reliability should be carefully verified. Signs are most important of all, especially in proving the truth of the history and the symptoms. Once the first aid student has made up his mind that certain signs are present, he can diagnose his case and begin the treatment. A sign means some definite evidence of abnormality. Thus, undue pallor, restlessness, incontinence, vomiting, swelling, movement where there ought not to be movement, stiffness, heat and numerous other signs may all be demonstrations that some unusual condition is in existence.

4. *The cause.*—If two motor cars are found at cross roads with the bonnet of one in the chassis of the other, and 4 or 5 persons are lying unconscious and bleeding on the roadway, it is clearly obvious that the general cause is a collision. It is when we come to the individual injury (for example, a broken tibia) that we must use our wits to discover how it was that the tibia snapped. Did it result from direct violence or from indirect violence? Was the patient knocked unconscious and, as he fell, " doubled up " his leg? These are the questions which are usually uppermost. Again the cause may still persist, as in the presence of sea water in the lungs occluding oxygen and causing asphyxiation. Or a hot piece of metal may be resting against the foot if a man injured in an explosion. We must also remember that more than one injury—multiple injuries—may result from one accident.

5. *The patient's environment.*—Whether a patient be found bleeding from the stomach in a miserable attic, snoring heavily with coma in a josshouse in Limehouse or lying by his bench with a wound in his head, we must always investigate the nature of the surroundings. The whole " atmosphere " of the emergency often gives us a helpful clue. The presence of machinery, electrical appliances, drugs, poisonous gases, fire, boiling liquids, grease on roads, ice on pavements, a mad dog, a swarm of bees, are all examples of the general evidence of the accident, while blood stains, empty bottles, an open razor blade, a revolver, crude instruments of suicide and many other such clues may give the more particular evidence sought for. In all cases, it is well to keep any clues, as they may come in useful later on.

Another aspect of the environment is the presence or absence of personal or material assistance. In populous areas it is never difficult to collect a crowd, and this means assistance in lifting, in sending messages, in fetching necessities and in provision of

temporary bandages, splints or dressings. All first aid is improvisation; each case must be treated according to the ruling circumstances and only the general principles can be laid down in textbooks. The first aider who uses her personal and material help to the best advantage is the one who thoroughly understands her job.

Next some sort of protection must be afforded to the patient before he is transported to the doctor. Occasionally the wait is a long one, and the situation may be an exposed one, therefore every possible precaution should be made against deterioration of the injured parts. It may be that the holding of an umbrella over the patient is sufficient, or it may be that the construction of a most elaborate bivouac out of greatcoats, sticks, blankets and various other handy things is essential to the welfare of the patient. Much depends upon the opinion of the first aider as to the possibility of rapid removal and this is governed by many considerations.

Lastly the question of transport comes in. In some cases the injured person can walk; at other times he requires a stretcher with 4 strong men. Between these extremes there are all degrees of transport methods (some crude, some scientific) governed by the type of injury, the length of carry, the nature of the ground and the availability of the vehicle, whether it be an old door improvised as a stretcher, or a modern ambulance.

The Essential Qualifications of First Aiders.—The St. John Ambulance Association has laid down 8 attributes necessary for perfect first aid. These are *observation, tact, resourcefulness, dexterity, sympathy, perseverance, discrimination, explicitness.* The person who is in full possession of all these faculties is to be envied, and the human being who is injured need have no fear when he is attended by one so qualified.

Treatment by First Aid Methods

In all emergencies, the first aider is limited by certain circumstances and he has only a few appliances available. The following main lines of treatment should be adopted.

1. *Remove the cause of injury, or the injured person from the cause, whichever is the more convenient.*

2. *Stop any bleeding at once.*

3. *Give the patient as much air as possible.* This may involve simply opening the clothing at the neck, keeping back the crowd or swabbing out the mouth. In drowning, when modern resuscitation appliances are not available, it may mean hours of artificial respiration.

4. *Rest the patient, and especially an injured limb.* Keep injured parts supported by pillows improvised from jackets, blankets or other suitable substances such as straw or lumps of turf.

5. *Promote warmth.* This is one of the great principles of first aid, since there is always a certain degree of depression of function known as shock. Improvise hot water bottles from tins and other containers; use hot bricks.

6. *Put a protective dressing on all wounds.* Pads can be made by folding handkerchiefs into small squares. Triangular bandages are used to keep the pad in position. Remove any obvious dirt from the wound but do not be meddlesome. There is no need for elaborate washing of wounds. The main thing is to get the wound covered up.

7. *Poisons must be got rid of speedily wherever they are.* If a poison has been swallowed, it can be removed by an antidote or an emetic. If it is in a wound it must be dealt with according to the nature of the causative agent.

8. *Do not remove too much clothing.* Particularly is this important in the case of scalds or burns, as the injured skin area so easily peels off with the removal of the garment. Only the garments near the wound need be cut or removed. In taking off the jacket, remove it by getting the uninjured arm out first. In some cases it may be necessary to slit the seam. Trousers may be slit up both seams. Boots should never be wrenched off. It is permissible to cut a boot in the middle line towards the toe. Underclothing can generally be cut freely.

9. *Give a stimulating drink, but do not give any alcohol.* Hot sweet tea, coffee, beef tea or milk may be better than whisky or brandy. The application of smelling salts is useful. Sponge the face with cold water. Put a hot water bag over the chest and upper part of the abdomen. Give a teaspoonful of *sal volatile* in a wineglassful of water.

10. *Do not conclude death has taken place because the patient is inert.* Never give up hope; many people suffering from shock are apparently dead.

11. *Send for skilled help as soon as possible, writing out, if you have time, a short note with the details of the case.* It is better to write a concise and legible note than to scribble down a lengthy report which is difficult to read. Use block letters when possible.

Knowledge of Anatomy and Physiology

In this work, the subjects of anatomy and physiology have already been fully treated, therefore nurses have ample facilities for understanding the various subjects discussed in the following chapters. The average first aider is required to know only the meagre outlines of these two sciences, therefore the nurse who is studying for the examination should find no difficulty in making her first aid knowledge perfect. She is recommended, however, to revise especially the anatomy and physiology of bone, circulation, digestion and respiration.

CHAPTER 2

HAEMORRHAGE

TYPES OF HAEMORRHAGE. ARTERIAL HAEMORRHAGE. VENOUS HAEMORRHAGE. CAPILLARY HAEMORRHAGE. EXTERNAL HAEMORRHAGE. TYPES OF WOUNDS. TREATMENT OF EXTERNAL HAEMORRHAGE. INTERNAL HAEMORRHAGE. BLEEDING FROM THE NOSE. BLEEDING FROM THE MOUTH. BLEEDING FROM THE LUNGS. BLEEDING FROM THE STOMACH. CONCEALED INTERNAL HAEMORRHAGE. BLEEDING FROM LARGE AND IMPORTANT VESSELS. COMMON CAROTID ARTERY. TEMPORAL ARTERY. FACIAL ARTERY. OCCIPITAL ARTERY. SUBCLAVIAN ARTERY. AXILLARY ARTERY. BRACHIAL ARTERY. RADIAL AND ULNAR ARTERIES. BLEEDING FROM THE HAND. THE FEMORAL ARTERY. THE POSTERIOR TIBIAL ARTERY. THE ANTERIOR TIBIAL ARTERY.

Haemorrhage, or bleeding, is the most serious sign in any accident and it is the first thing to be dealt with; every second is precious, therefore it is essential to have the bleeding stopped in the most expeditious way, even although the method adopted may be crude. All degrees of haemorrhage are to be found, from that of the cut finger to the vital loss by the opening of one of the great arteries. It is best to divide the subject into four sections, the first dealing with the types of bleeding, the second with external bleeding, the third with internal bleeding and the last with the treatment of bleeding from the large and well known vessels.

Types of Haemorrhage

There are 3 types of haemorrhage as described below.

1. **Arterial Haemorrhage.**—Since there is a pulse in every artery as a result of the beating of the heart, it follows that when an artery is cut the blood comes out in jets or spurts and has a bright red appearance.

2. **Venous Haemorrhage.**—Bleeding from a vein is shown by oozing of the blood, which is not under pressure; severe bleeding may occur from the open end of a large vein. The blood is purple-red in colour.

3. **Capillary Haemorrhage.**—When the blood escapes from the capillary network, there is very little pressure and, unless a very large area is involved, the loss of blood is not serious. Clotting soon takes place and generally the bleeding stops naturally. The blood is red. This is the type of bleeding found in the minor domestic casualties.

External Haemorrhage

Types of Wounds.—External haemorrhage occurs from a break in the skin which may or may not involve the deeper tissues. Wounds vary in size according to the accident. They are classified as follows.

1. *Incised wounds.*—These are caused by any sharp edged thing like a knife, the lid of a tin or a razor. The cut-throat incision provides the best and most extensive example of the incised wound. In an incised wound the edges are clean, there is no raggedness or tearing and the bleeding is difficult to stop.

2. *Lacerated wounds.*—This is the commonest type of wound in the home, in the factory, in the street or on the battlefield. It is caused by tearing and destruction of tissues, so that a raw, ragged and gaping wound is made. Owing to the disorganization and laceration of the tissues, the blood vessels are not cleanly cut; therefore the blood clots easily and haemorrhage is not so severe as in incised wounds (see pp. 145–147).

3. *Contused wounds.*—A contused wound is one accompanied by swelling, like the " bump " of childhood days. Any sudden impact of a blunt instrument, the best example of which is the policeman's truncheon, will make a slight lacerated wound, surrounded by great swelling and contusion. The tissues rapidly become discoloured.

4. *Punctured wounds.*—The prick of a needle or pin is the commonest example. Although no marked bleeding may occur, the danger of sepsis is very great owing to the depth of the wound. More serious punctured wounds are those of stabbing with a bayonet or stiletto, or the through-and-through puncture made by a sharp nosed bullet. In war wounds, it is often difficult to find the entrance of the bullet which may have done much damage in its passage.

Treatment of External Haemorrhage.—The principles laid down on pp. 310 and 311 must be observed. Each wound must be considered according to its peculiarities, but if we remember to stop the bleeding, to protect the wound and to treat the general condition of the patient, these three main lines of treatment will generally succeed in tiding him or her over the emergency. If a clot is forming, or has formed, it should on no account be disturbed. This is Nature's own way of closing the

wound; not only does a clot shut in the blood, but it shuts out poisonous bacteria and prevents sepsis of a local or general character. The treatment of the general condition depends upon the extent of the shock. Some people faint. This is not unfortunate, as it causes a slight temporary depression of the circulation and keeps the patient still during vital minutes. In severe haemorrhage, there is always shock with great depression, and this must be dealt with by applying hot water bottles to the extremities, covering the patient well up and trying to restore the circulation. Care should be taken to warm the patient slowly and not to overheat him. The giving of a stimulant is a debatable matter; if any alcohol is given it should be well diluted.

Dressing the wound.—Large arteries bleeding profusely may demand the application of drastic and forcible methods of stoppage. But the smaller wounds require usually the simplest toilet and afterwards a pad and bandage. The great essential is to get on with the job, avoiding fuss and perfunctory manoeuvres. In certain cases it is advisable to remove the grease and dirt as much as is practicable, because septic organisms including those of tetanus (or lockjaw) may collect in the wound, but to use lotions such as soap and water, and very doubtful " antiseptics," is doing more harm than good, however nice the wound may look after the treatment is completed. Various solutions are used for wounds—iodine, picric acid, antiseptic paints and varnishes, gentian violet and many other germicides. These may be applied by special drop bottles, which are nowadays part and parcel of every first aid kit, or may be dabbed on the wound by gauze. As a general rule solutions should be allowed to dry before the pad is applied. The latter consists (in ideal conditions) of several layers of fine sterile gauze covered by a layer of cotton wool, about half an inch thick. A little imagination of the circumstances of most accidents will convince the reader that this policy of perfection is often impossible, therefore we have to be content with strips of cotton or linen, improvised from underclothing or handkerchief, covered by less refined dressings devised by the resourceful bystanders. The pad is kept in position by bandages made from scarves or handkerchiefs folded into a triangle and then folded twice or three times on themselves until a narrow strip is formed. By this method we make sure that bleeding is controlled and that sepsis is prevented as much as is practicable in the circumstances. In first aid the maxim is to touch the tissues as little as possible, to cover up the wound as quickly as possible and to disturb Nature's process of recovery as little as possible.

How to deal with arterial haemorrhage.—Suppose the pad and bandage method does not succeed in stopping the bleeding.

Occasionally, after the dressing has been on for a few minutes, we find that there is great oozing and the red colour spreads all over the bandage. This may be a salutary thing, the prelude to clotting. In some cases, however, the loss is so severe that we have to re-examine the wound and find whether an artery is bleeding. Generally the routine examination proves the type of haemorrhage, and if it is red and spurting, we must adopt one or other of the following measures.

FIG. 170.—ESMARCH TOURNIQUET WITH LONG RUBBER BANDAGE. (*By courtesy of the Surgical Manufacturing Co., Ltd., London.*)

1. Compression by the fingers of the bleeding point; it may be necessary to keep the finger on the spot until a doctor arrives with a pair of artery forceps. Sometimes the application of the pad with specially thick gauze and wool will suffice to stop arterial bleeding. When both these methods fail, either because the artery is too badly torn or too big to be controlled by simple pressure, we are forced to apply the thumb, reinforced by the fingers if necessary, over the artery at a definite pressure point (Fig. 174), on the side of the wound next the heart and as soon as possible substitute a tourniquet. The latter, as its name implies, is something which is twisted. The simplest one is made by tying a triangular bandage round the limb, passing a small stick below the loop and twisting it until the circulation is stopped completely. If a small cork, rolled in a handkerchief and placed immediately over the vessel, is also used, the pressure on the trunk of the artery will be assured (Fig. 171). Various tourniquets are made, and they are part of the general first aid kit (see Fig. 170). The improvisation of tourniquets, however, from handkerchiefs, scarfs, pebbles, coins, nuts, spanners, sticks, and rulers is just as

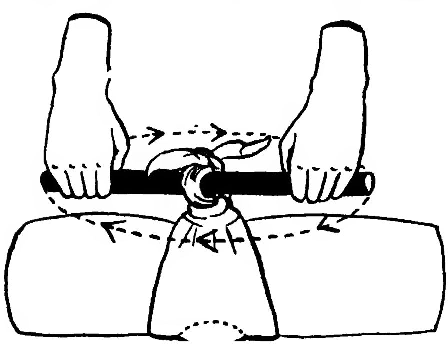


FIG. 171.—IMPROVISED TOURNIQUET, MADE BY A TRIANGULAR BANDAGE AND SMALL STICK. A SMALL PAD IS SHOWN OVER THE VESSEL INVOLVED.

important as the makeshift dressing on the wound. Here again it is a matter of applying commonsense methods.

Tourniquets stop all circulation, so the point arises as to their dangers. The question asked by all first aiders is, "How long should the tourniquet be kept on?" This is a controversial matter and opinions vary. As might be expected, much depends upon the case, the seriousness of the injury and the state of the patient. In very bad cases (e.g. in extremely severe haemorrhage, when life has to be considered before limb) it must never be taken off. During the time the patient is in the hands of the first aider, any recurrence of haemorrhage must be prevented. But sometimes there is no harm in gently and carefully reducing the pressure of the tourniquet so that some blood, under reduced pressure, reaches the part and keeps the tissues bathed in fresh blood. It is a matter of great experience on the part of the attendant to know exactly how long to keep the tourniquet in position; a continuous period of half an hour is the limit, but generally a doctor is on the spot by that time.

Treatment of other forms of external haemorrhage.—Other forms of external haemorrhage e.g. capillary bleeding and venous bleeding do not demand the same attention as the arterial variety. Capillary haemorrhage may be dealt with exactly as described in the paragraph on the dressing of the wound (p. 314). Venous haemorrhage may be copious and it is better to keep the patient flat on his back, the limb being held in the elevated position. Bleeding may be controlled by putting a bandage on the side of the wound most distant from the heart, since all venous blood runs towards the heart. In the same way garters or other constrictions should be removed on the side of the wound nearest the heart, because they prevent the return of the blood.

Points in the general management of haemorrhage.—Apart from local treatment and the application of bandages and tourniquets, or improvisations of such, there are certain principles which apply to all serious cases: 1. the patient is better sitting than standing, and he is better lying down than sitting; 2. unless there is a fracture, the limb should be elevated, and kept well supported; 3. shock should be prevented by making the patient as warm and as comfortable as possible.

Internal Haemorrhage

Internal haemorrhage may come from the vessels of the lining of the nose (epistaxis), from the lung (haemoptysis), from the stomach (haematemesis) or from the inside of the mouth (from tooth sockets, tongue or gums). In all these conditions the blood has an external outlet. The gravest form of internal haemorrhage is that which occurs in the cavity of the abdomen, and

which may be due to bleeding from the stomach or bowel, to rupture of the liver or kidney, or to the internal haemorrhage from an ovarian pregnancy. In all cases of this type there is not any external outlet and therefore pressure symptoms and great shock are the rule.

Bleeding from the Nose.—Occasionally this is a great relief, especially to the person with high blood pressure, when it is a timely warning of the general condition, or to the young person with polypus when the latter is not serious and can easily be dealt with surgically. Epistaxis also occurs accidentally. The first aid treatment consists of putting the patient on a chair in a reclining position before an open window, his head well back, and the hands above and behind the head. A towel should be spread round the neck in order to prevent the clothes from being soiled. Over the bridge of the nose, cold water cloths or crushed ice in a handkerchief should be put, and the bridge of the nose may also be pinched. Another good plan is to rest the nape of the neck on a half filled hot water bottle containing ice cold water. All tight collars or other clothing causing pressure should be loosened. The patient should sit still, breathing through the open mouth for 5 minutes; he should be told not to blow his nose. In very bad cases, the nostrils can be plugged with ribbon gauze soaked in adrenaline.

Bleeding from the Mouth is treated by giving ice to suck, alum mouthwash, hot water or hot salt and water. The patient should preferably adopt the position at the open window, described above. A tooth socket bleeding badly after dental treatment may be plugged with adrenaline gauze, or a very small cone-shaped piece of cork may be covered with fine lint and by biting on it the patient may succeed in stopping the bleeding. Small plugs of cotton wool may be equally efficacious. Manual pressure often succeeds, but the copious saliva tends to keep the vessels open. It should be kept in mind by the first aider that blood may appear in the mouth in considerably quantity as the result of injury of the pharynx, oesophagus, larynx or trachea.

Bleeding from the Lungs.—In bleeding from the lungs (haemoptysis) in early phthisis, the sputum has a rust-like colour or is streaked with blood. About a dessertspoonful of blood may be lost every day, which is quite usual. In bleeding from a ruptured artery in a cavity, the condition is very serious and often fatal, as there is no method of putting pressure on the blood vessel involved. The patient should be kept extremely quiet,' an ice-bag being applied to the chest, and ice given to suck. He should be encouraged to lie on the injured side so that the healthy lung can be allowed free and unrestricted movement.

Bleeding from the Stomach.—When an ulcer of the stomach ruptures, there is vomiting of churned-up blood which looks like a collection of coffee grounds. Particles of food may be mixed with it. An ice bag should be applied over the pit of the stomach, and the only thing given by the mouth should be ice, which has doubtful action.

Bleeding from the Kidney.—Great pain with subsequent shock and abdominal swelling may indicate injury to the kidney. The diagnostic point in this case is the appearance of blood in the urine.

Concealed Internal Haemorrhage.—In cases of intra-abdominal bleeding, the great shock must be treated, as already described. The cold, clammy skin, with its beads of perspiration, is typical, also the restless demeanour of the patient, which is caused by a condition known as air hunger. Yawning, sighing, rapid breathing and failing pulse lead to semiconsciousness. It is a very serious condition and the patient should be kept warm, lying in a comfortable position, out of a draught; great care should

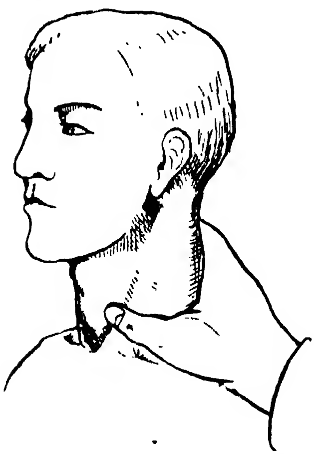


FIG. 172.—STOPPING BLEEDING. CAROTID ARTERY.

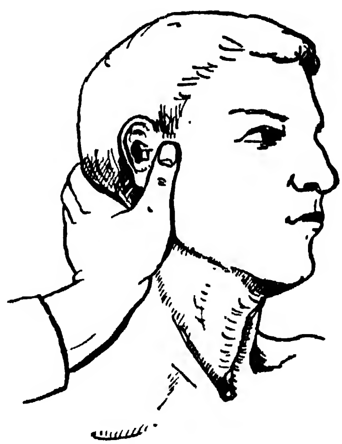


FIG. 173.—STOPPING BLEEDING. TEMPORAL ARTERY.

be taken in observing the general condition and recording the pulse volume and rate.

Bleeding from Large and Important Vessels

The nurse is recommended to make herself fully acquainted with the course of the main arteries and veins (see pp. 153–167), since the treatment of these conditions depends upon pressure

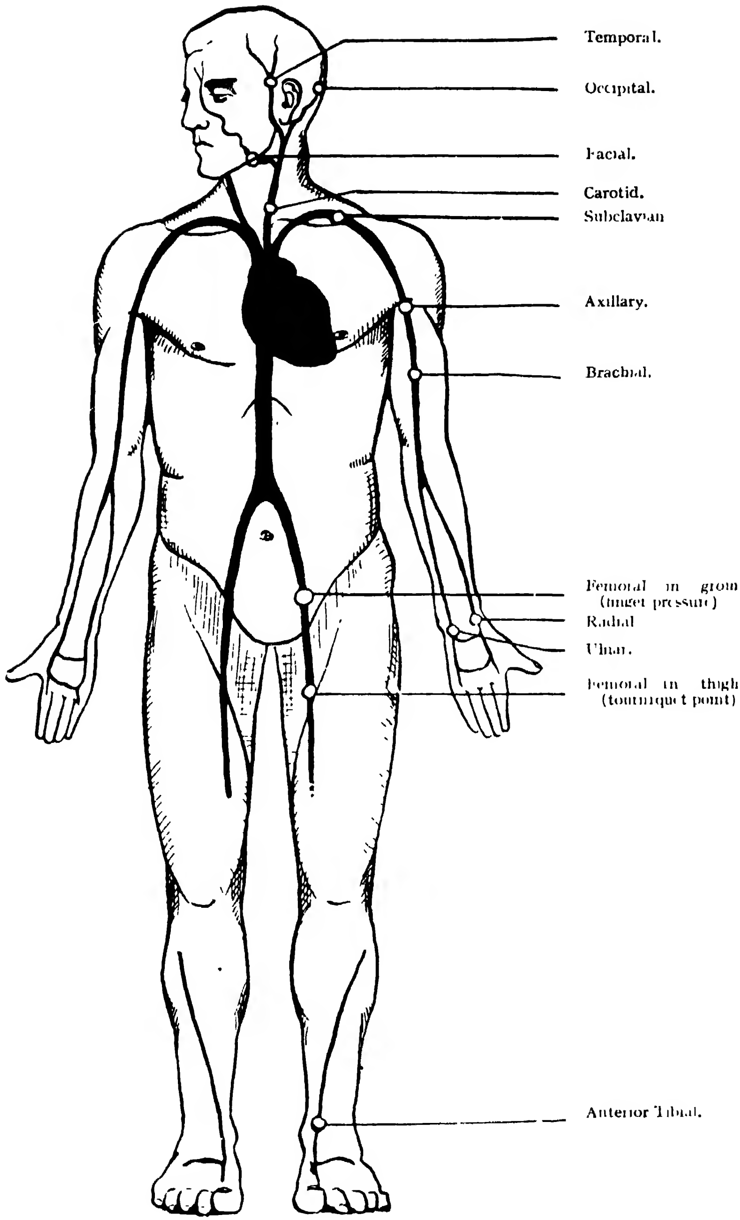


Fig. 174.—Pressure Points.

applied at points at which the arteries become superficial. These landmarks, already referred to, are known as pressure points and are indicated in Fig. 174. In an emergency, there may be no time to put on a tourniquet; in any case the first thing to do is to put pressure on the specific point and to stop the bleeding at the wound. In most cases the pressure points have a background of bone, thus making it very easy for us to compress the artery against it. The procedure in each case is summarized below.

Common Carotid Artery.—Press the thumb in the groove behind the larynx; the beating of the artery will be felt. Now firmly press the tip of the thumb on the artery until beating is stopped by the bone of the vertebral column. The pressure

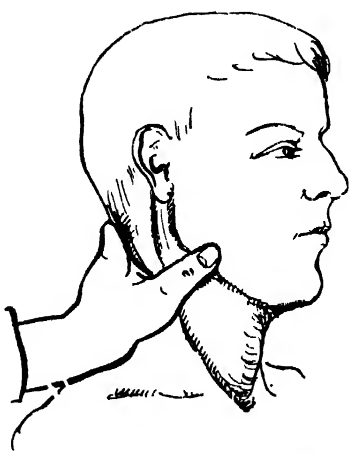


FIG. 175.—STOPPING BLEEDING. FACIAL ARTERY.

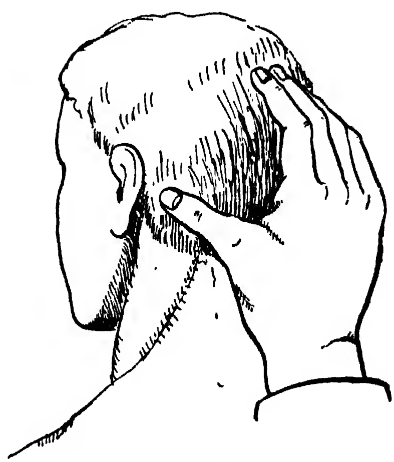


FIG. 176.—STOPPING BLEEDING. OCCIPITAL ARTERY.

should be applied inwards and backwards. Occasionally the upper part of the carotid artery and the jugular vein require pressure with the thumb of the other hand. Tourniquets cannot be applied; the only way to manage the case is to have assistants who take turns of pressing until the doctor appears (Fig. 172).

Temporal Artery.—This is often seen just in front of the ear (Fig. 173). It can easily be felt beating. Pressure is applied as shown in the diagram.

Facial Artery.—This artery crosses the lower jaw about $1\frac{1}{2}$ inches in front of the angle of the mandible. Bleeding from any part of the cheek, chin, lips or nose can be controlled by putting on pressure as shown in Fig. 175. In some cases the bleeding

can be stopped by gripping the cheek between the thumb and the index finger.

Occipital Artery.—If there is marked bleeding from the back of the scalp, it can usually be controlled by pressure with

FIG. 177.—STOPPING BLEEDING. SUBCLAVIAN ARTERY.

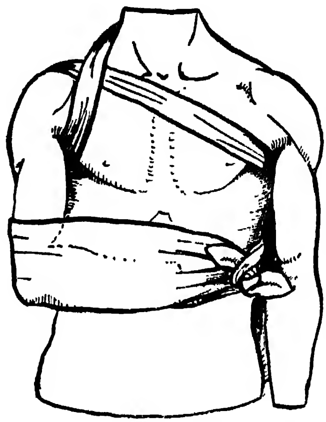


FIG. 178.—STOPPING BLEEDING AXILLARY ARTERY. (ST. JOHN METHOD.)

the thumb on the artery at a point (Fig. 176) about 3 inches behind the middle of the ear.

Subclavian Artery.—Deep haemorrhage in the neck can be controlled by this method. The left hand should be used for the right side of the neck, and vice versa. The patient's head

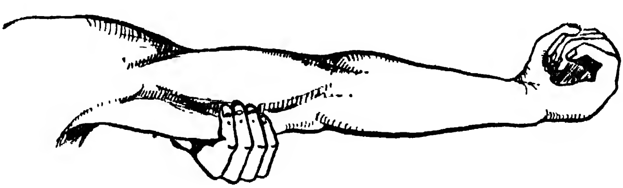


FIG. 179.—STOPPING BLEEDING. BRACHIAL ARTERY.

is inclined towards the first aider, so that the sternomastoid muscle is thus relaxed; at the same time the shoulder should be depressed. Grip the root of the neck with the thumb in front and the fingers behind. Feel for the hollow lying above the clavicle and to the outside of the tendon of the sternomastoid muscle. Press the artery firmly against the first rib (Fig. 177). By this method, bleeding in the armpit can also be controlled.

Axillary Artery.—It is difficult to close this artery by pressure, as the contents of the axilla are soft and non-resistant. The artery can be felt beating if the fingers are pressed backwards under the lower border of the pectoralis muscle, and thus behind the anterior fold of the axilla. The St. John method of pressure is an ingenious one. A pebble or hard ball, a little bigger than a golfball, is rolled up in a handkerchief and placed well up in the armpit. A narrow bandage is made by folding a triangular bandage, and its centre is put on this pad. The ends are then drawn up, crossed as a figure-of-eight and tied under the other armpit, while the arm of the affected side is tied to the body as shown in Fig. 178.

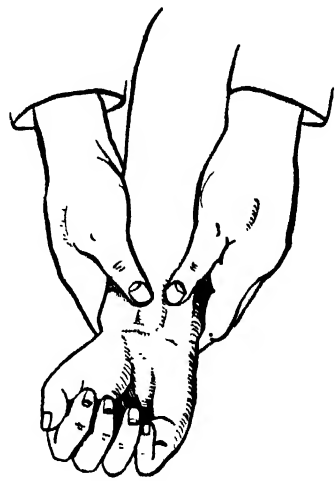


FIG. 180.—STOPPING BLEEDING. RADIAL AND ULNAR ARTERIES.

Brachial Artery.—The best place to stop bleeding in the brachial artery is at a point on the medial border of the biceps about the middle of the upper arm. Here the artery is pressed firmly against the underlying humerus bone (Fig. 179). This method can be used to control bleeding of the whole of the arm, although as an emergency measure, pressure just above the

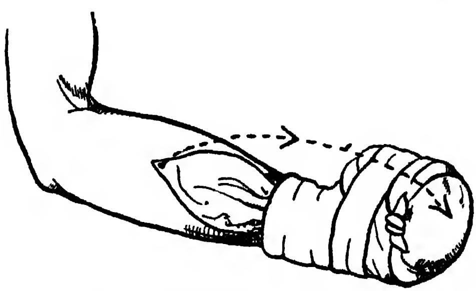


FIG. 181.—STOPPING BLEEDING. VESSELS OF THE HAND.

middle of the bend of the elbow will also stop bleeding in the forearm and hand; it is often a very painful method.

Radial and Ulnar Arteries.—These arteries become very superficial at the wrist. Pressure over the site of the pulse

(radial artery) and over the ulnar artery, at a point about ½ inch from the medial border at a level 1 inch above the wrist, can be kept up for a time by using both hands as shown in Fig. 180. Bleeding in the palmar arches can thus be controlled. If pressure must be kept up for any length of time, a cork cut longitudinally into two halves, with the rounded portion of each half placed over the radial and the ulnar arteries, will suffice as a tourniquet pad, while the tourniquet itself is provided by a handkerchief firmly fixed round the wrist.

Bleeding from the Hand.—If there is not any fracture or foreign body present, make a pad by rolling a small cork in a

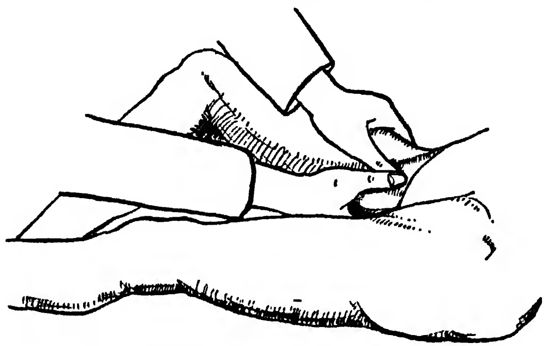


FIG. 182.—STOPPING BLEEDING. FEMORAL ARTERY.

handkerchief or by simply rolling up a handkerchief into a pad. The patient is told to grip this tightly. Fold a large handkerchief into a triangle, and lay the base of the triangle about the level of the wrist. The back of the hand should thus lie about the centre of the triangle. The apex of the triangle is pulled over the knuckles and towards the wrist by the patient and kept there, while the operator crosses the ends round the wrist over the point, brings them round again twice over the thumb and fingers and ties them firmly. The point is left as a tag above the wrist; pull it forward and fix it with a safety pin over the knuckles. Put the hand in the opening of the patient's jacket (Fig. 181).

The Femoral Artery.—This can be pressed against the pelvic bone as it comes to the front of the thigh in the femoral triangle. The exact point of pressure is shown in Fig. 174, and corresponds roughly to the centre of the fold of the groin. By this method, we can stop all bleeding of the lower extremity. The patient should be put flat on his back, while the first aider kneels beside him, looking towards his head. Draw the thigh slightly up, and, gripping the thigh with both hands, press firmly with one

thumb on the pressure point, reinforcing it by pressure with the other thumb. This is a very tiring process, and requires an assistant to act as relief. It must be kept up until a tourniquet can be applied as far up the thigh as possible. The pad in this case must be the size of a cricket ball and should be fixed by a simple tourniquet. The line of the femoral artery is one drawn from the centre of the groin to the medial side of the knee.

The Posterior Tibial Artery.—To control haemorrhage in the foot, raise the leg and apply pressure forwards and outwards to the posterior tibial artery just behind the medial malleolus.

The Anterior Tibial Artery.—The best place to press on this artery is at a point about the middle of the front of the ankle (see Fig. 174). The pressure should be applied backwards, the leg being in the elevated position.

CHAPTER 3

FRACTURES AND SPRAINS

CAUSES OF FRACTURES. CLASSIFICATION OF FRACTURES. SYMPTOMS AND SIGNS OF FRACTURE. TREATMENT. FRACTURES OF INDIVIDUAL BONES. SKULL. LOWER JAW. SPINE. RIBS. CLAVICLE. SCAPULA. HUMERUS. FOREARM. CARPUS, METACARPUS, PHALANGES. PELVIS. FEMUR. PATELLA. LEG. FOOT. SPRAINS.

It should be clearly understood that in this chapter fractures and sprains are discussed only from the first aid point of view. The approved and up-to-date methods of professional treatment, including splintage, are fully dealt with in Section V, Chapter 12; Section VI, Chapter 1; Section IX, Chapter 4.

A fracture may be defined as the condition which is set up when a bone is broken into two or more pieces.

Causes of Fractures

Direct Violence.—Any unusual force applied at a certain part of the bone may cause the bone to break. When a heavy piece of machinery falls on the middle of the tibia, the bone cannot stand the strain and is snapped across. Missiles hurled with velocity (e.g. ammunition of any kind) hit the bone with such force that it breaks in the impact.

Indirect Violence.—This is a very common way of breaking bones. The site of fracture is at some part distant from the place at which the impact occurs. For example, a person, in falling heavily to the ground, puts out his hand to break his fall. The force of the ground hitting the hand is transmitted to the collar bone, which snaps. People who fall downstairs usually double up the leg below them, and may thus fracture the femur.

Muscular Action.—Occasionally, sudden contraction of a powerful group of muscles (e.g. the quadriceps femoris group) may cause a fracture of the bone to which they are fixed (e.g. the patella). This occurs in athletes and others of powerful muscularity.

Classification of Fractures

Fractures can be classified in 2 ways: 1. according to the injury done to the surrounding tissues; 2. according to the damage done to the bone. In class 1 the following are the chief types.

Simple Fracture.—The skin is not broken. There is very little damage to the tissues in the vicinity of the fracture. The bone is divided, split or cracked.

Compound Fracture.—In addition to there being broken bone or bones, the tissues are torn or otherwise injured, a break in the skin allowing the outside air to reach the bone and thus introducing dangers of sepsis from the numerous germs present. In some cases the bone may be seen sticking out of the wound; in others the tissues may be destroyed to expose a considerable portion of the broken bone. In bullet wounds and other deeply penetrating wounds of similar type a small channel may lead down to the wound.

Complicated Fracture.—In this type, there is the complication of severe internal injury. Thus, if a rib is driven into the kidney as a result of fracture, or if a piece of the table of the skull becomes embedded in the brain, serious interference with the work of the body occurs, apart from the actual fracture. Occasionally a simple fracture becomes compound or complicated by undue mobility of the patient or by first aid methods which do not run on approved lines. This is a very important point in deciding about the method of treating the emergency. The cure should never make the injury worse.

In class 2 several types are described of which the following are the chief.

Comminuted.—Several small pieces of bone represent a fracture area.

Impacted.—One bone is telescoped into the other for a short distance.

Multiple.—More than one bone broken, or one bone broken at more than one spot.

Oblique, Longitudinal or Transverse.—These are terms used to describe the line of break.

Greenstick.—When the bone contains much cartilage, as in young children, the fracture is not complete and the effect produced is the same as that obtained when we try to bend a piece of green wood across the knee (Fig. 183).

Symptoms and Signs of Fracture

1. **Pain.**—At the site of the fracture and in the surrounding tissues.

2. **Swelling.**—Owing to leakage of blood, gathering of fluids and so on, the region of a fracture quickly fills up, and the swelling forms a natural cushion round the injury, making it difficult to ascertain whether there is a fracture or not. It is well always to suspect fracture, however.

3. **Deformity of the Limb.**—The patient holds the affected limb in a peculiar way and the natural outline of the limb may be changed owing to the swelling and to the position of the ends of the broken bone.

4. **Shortening.**—When a bone is fractured, one group of muscles pulls one fragment in a certain way, while another pulls the second fragment in another way, so that there is overriding and shortening (Fig. 184).

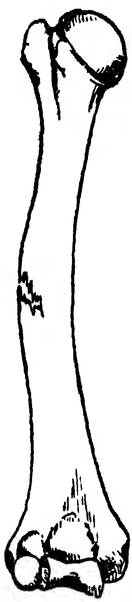


FIG. 183.—GREENSTICK FRACTURE.

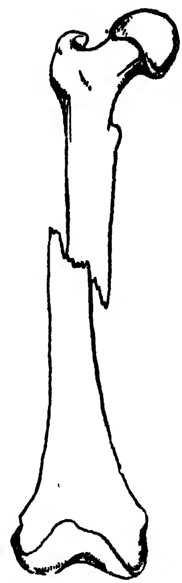


FIG. 184.—HOW SHORTENING OCCURS IN A FRACTURED BONE.

5. **Irregularity of Bone.**—Sometimes (e.g. in fracture of the clavicle) the injury can be felt distinctly as a marked irregularity on the otherwise smooth surface of the bone. When there is any swelling, as described above, this sign as a rule is not in evidence.

6. **Movements.**—A grating of the ends of the bone, called crepitus, and sometimes a distinct movement at the fractured part may be demonstrated, but first aiders are cautioned against the deliberate demonstration of this sign. It should be left to experts, who themselves are most conservative in testing for this property of broken bone.

7. **Loss of Power.**—The limb is usually flaccid and useless.

8. **History.**—The bystanders may be able to describe the accident; the snap of the fracture may have been heard; clothing may be torn.

Treatment

In treating fractures by first aid methods, the aim should be to immobilize the limb, generally by fixing the joint above and below the site of fracture. This ensures that the patient can be transported without further injury and with the maximum comfort, while the danger of converting a simple fracture into a compound or complicated fracture is minimized. The chief lines of treatment are given below.

1. **Treat the Patient where he Lies.**—Statistics show that there is an enormous amount of damage done by allowing people with broken bones to be moved to more convenient places before splints are applied. Treat the fracture on the spot, unless conditions are such that it is dangerous to leave the patient where he is. For example, during a prolonged air raid, it may be necessary to get the casualties away from the place at which bombs are still falling or at which masonry is collapsing.

2. **Stop any Bleeding First of All.**—This is discussed in the previous chapter.

3. **Make Arrangements to Support and Fix the Limb.**—This is a preliminary to splinting and is necessary because the patient may be restless. Often it means supporting the limb with both hands.

4. **Treat the Shock.**—(See p. 314.)

5. **Extension.**—This should be done very carefully, and if there is evidence of a considerable amount of resistance it should not be continued. It consists of very gentle traction on the foot or hand, so that the fragments are replaced as nearly as possible in their natural alignment and the shortening overcome. Once the shortening is reduced, the limb must not be let go until splints are fixed. Never put extension on in the case of a compound fracture.

6. **Fix Splints.**—The simplest splints used in hospitals consist of plain wooden spars of various lengths and of widths ranging from 1 inch to 4 inches. In accidents, we may not have such useful appliances, but we can always commandeer the spars from fences, wood from packing cases, umbrellas, walking sticks, broom handles, golf clubs, hockey sticks, gun or rifle and other suitable improvised material. There is no need to remove clothing, as the splint acts better when padded and sometimes it is possible to make pads with grass or handkerchiefs. If the splint is long enough to extend above and below the upper and

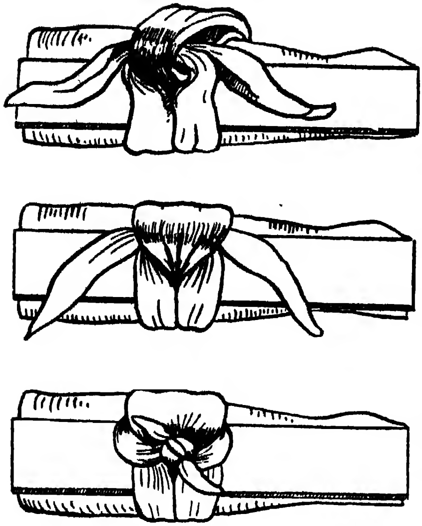


FIG. 185.—METHOD OF FIXING BANDAGES OVER SPLINTS.

lower joints respectively, and if it is wide enough to take the weight of the limb, it is satisfactory. When the fracture is in one of the legs, use the sound leg as a supplementary splint, fixing the injured leg to it by a series of bandages.

7. **Bandages.**—All that is required are plenty of large handkerchiefs folded into triangles. These can be further folded into the broad or the narrow bandage as described on p. 314. In fixing splints to the limbs the narrow bandage is best. It should be passed carefully below the arched parts of the limb e.g. knee or small of the back. The best way to do this is to fold a narrow bandage once on itself and pacing a thin splint in the loop so formed push the bandage below the limb. For the trunk, the broad bandage may be required. This is usually fixed at the side opposite to the injury, unless it is used to fix the long splint of a broken thigh bone, when the knots are tied over the splint. When dealing with the arm or the leg we can use the narrow bandages in two ways. The ends may be passed round twice or more, and tied in reer knots on the outside of the outer splint. The other method consists of passing the loop (made as above for passing the bandage under the limb) still farther on and bringing it over the outside splint. By threading the ends of the bandage through the loop in opposite directions a very firm knotted bandage can be made. Great care should always be taken not to tie the

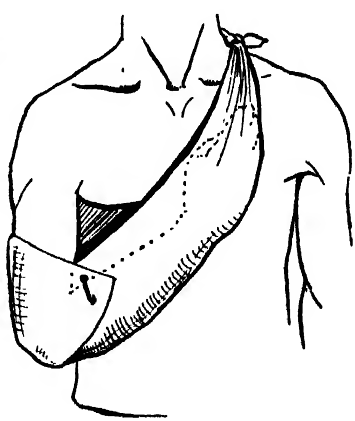


FIG. 186.—TRIANGULAR BANDAGE APPLIED AS A SLING.

bandages too tightly and thus press on the nerves or blood vessels; this would stop the circulation.

8. **Slings.**—In the upper extremity, a sling is required for support (Fig. 186). This can be made from a large triangular bandage. In some cases it is necessary to use a scarf or the opening of a blouse or coat.

9. **Stretcher Cases.**—On no account allow anyone with fracture of the pelvis, the spine or the leg to try to walk. Such patients should be removed on a stretcher.

Fractures of Individual Bones

Skull.—Two areas are chiefly involved, the vertex and the base. Fracture of the former is generally due to direct violence as e.g. when something heavy descends, hitting the top of the head. Fracture of the latter is usually caused by indirect violence and often results from a jolt transmitted up the spine when a person falls heavily on the feet or in a sitting position. In both cases, unconsciousness gradually supervenes. A special feature of fracture of the base is bleeding from the ears. There may be bleeding from the nose and mouth, and if the orbit is fractured the eye is bloodshot. The treatment consists of keeping the patient quiet and applying cold water cloths to the head. Fracture of the skull is always a grave condition.

Lower Jaw.—This is usually the result of a hard blow. The jaw cannot be moved without pain, the bite of the teeth is irregular and there may be bleeding from the mouth. Crepitus can be elicited by very gentle manipulation. The treatment consists in steadying the lower jaw against the upper with the palm of the hand, then in tying a narrow bandage over the head, with the point of the jaw in the middle of the bandage as shown in the diagram (Fig. 187). Another narrow bandage is passed over the chin just below the lower lip, and the ends are tied at the nape of the neck. The long tags remaining are passed forward, each one joining a tag of the first bandage and being firmly tied in reef knots.

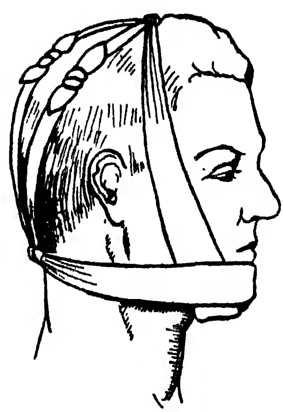


FIG. 187.—FRACTURE OF LOWER JAW.

Spine.—The spine may be injured in the same way as the skull—by direct or by indirect violence. A " broken neck " is a fracture of the vertebral column in the

cervical region. All spinal fractures are very dangerous owing to the proximity of the spinal cord; several of the vertebrae are usually displaced. Paralysis below the level of the fracture is common. The greatest care must be taken in handling these patients. The less movement there is the better; it is advisable to bandage together the legs, thighs and feet. If it is possible, the patient may be rolled gently over on to his back, then the shock should be treated and hot water bottles and covering applied. In the event of an ambulance not being available, and if the question of shelter is urgent, the patient must be carefully transferred to a wide stretcher improvised out of a shutter or door as long as, and slightly broader than, the patient. By passing bandages under the head, scapulae, hips, thighs and calves, and attaching the ends to poles, a litter can be made which can be raised very carefully by 4 bystanders while the stretcher is pushed under the patient.

Ribs.—A fracture of the ribs may involve more than one rib, and generally the 5th to the 9th ribs suffer most severely, the fracture occurring at the side of the thorax. Sometimes indirect violence causes outward displacement of the ribs; usually, however, the fracture is the result of direct violence and is accompanied by inward displacement. This may also cause a complicated fracture owing to lung damage, such as perforation of the pleura, setting up spontaneous pneumothorax; pneumonia may ensue. There is a danger of injury to the liver or spleen when fractures occur at the lower part of the chest. The signs are typical. The patient has a severe shooting pain when he takes an ordinary breath, therefore he has to breathe in a very shallow fashion. Any blood stained sputum should be regarded with apprehension as it indicates that the lungs are injured. Internal bleeding from the liver, spleen or kidneys, indicated by swelling, pallor and shock, shows that dangerous abdominal injuries have occurred. In simple fractures, all that is required as a first aid measure is the application of two broad bandages, the lower overlapping the upper for about 3 inches over the broken rib. This gives double support. A scarf or towel, 8 inches wide, may also be fixed very tightly round the chest like a binder; it should be fixed with several safety pins. The arm on the injured side should be carried in a sling. If there is any suspicion of internal injury, it is wrong to apply any constriction round the chest. The patient should be laid down with his body bent over to the side on which the fracture is situated, and pads or cushions built round him to give support. In haemorrhagic states, ice can be given internally and externally. In moving the patient, the arm on the injured side should be supported by the attendant until the hospital is reached; a large sling may be applied if the patient is able to tolerate the discomfort.

Clavicle.—This is the commonest fracture of the body, occurring often in the hunting field. The circumstances are usually that the victim, when thrown heavily, instinctively puts out his hand to save himself and so receives indirectly a sudden stress at the middle of the collar bone. The aspect of the person who has just fractured his collar bone is unmistakable. He holds the point of the elbow of the affected side with his other hand and bends his head towards the affected side in an endeavour to take the strain off the broken fragments. The displacement is also typical, the sternomastoid muscle drawing the inner fragment up while the outer one is depressed by the shoulder muscles. The slight overlapping can be felt. If possible, strip the patient to the waist. A stout pad, about 2 inches by 4 inches, made by rolling up a scarf, should be out well up in the axilla, while the arm on the injured side is supported, the shoulder braced back and a sling applied as shown in the illustration (Fig. 188). It is advisable to fix the arm to the side by another broad bandage which passes over the point of the elbow and is tied firmly on the sound side of the body. Make sure by testing the pulse that the circulation is not stopped.

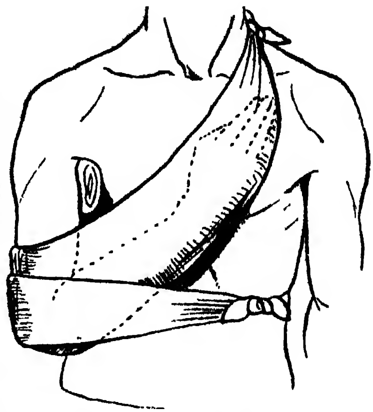


FIG. 188.—FRACTURE OF COLLAR BONE

Scapula.—This is not very common. It can be dealt with by making a figure-of-eight with a broad bandage over the injured side and under the other armpit and by putting the arm of the injured side in a sling.

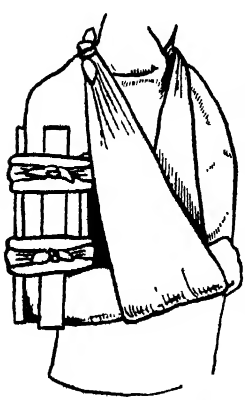


FIG. 189.—FRACTURE OF HUMERUS (SHAFT).

Humerus.—The three common sites are 1. head of the humerus; 2. shaft; 3. in or above the elbow joint.

1. *Head of humerus.*—The arm should be put out of action by tying a broad bandage round the middle third of the upper arm and fixing it tightly by a knot on the sound side of the body. A small sling should be suspended from the neck to support the wrist.

2. *Shaft.*—The break usually occurs just above the mid-point. First place the wrist in a small sling, thus making a right angle between the upper and lower arm. Take 3 wooden splints, reaching, when possible, well above the shoulder and well below

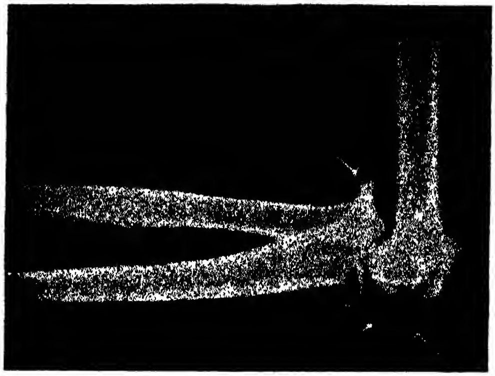


FIG. 190.—FRACTURE OF THE ELBOW JOINT.
This x-ray shows that dislocation is also present.

the elbow and 2½–3 inches wide; fix them by 2 narrow bandages, as follows: one over the biceps, one on the lateral side of the arm, and one on the triceps (Fig. 189).

3. *Elbow.*—Swelling quickly occurs, and the only proof of fracture is the x-ray photograph. Children are commonly affected, and there is a good deal of displacement (Fig. 190). If the accident occurs in the house, do not put on any splints, but lay the arm carefully on a cushion and be content with the application of a cold water bandage until the doctor comes. When treating a case of this type outside, a right-angled splint should be made by tying two thin rectangles of wood together as shown in the illustration (Fig. 191). The essential is that a complete wooden frame should be provided, one limb of which extends from above the shoulder to beyond the elbow, while the other extends from beyond the elbow to the tips of the fingers. This frame is then fixed to the outside or

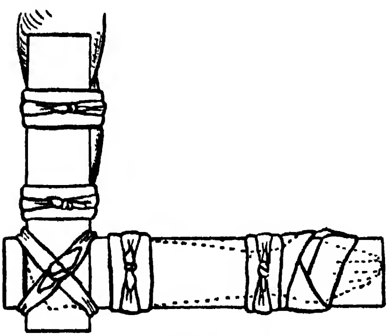


FIG. 191.—FRACTURE OF ELBOW AND OF FOREARM.

inside of the arm (as more convenient) by bandages. Support the wrist by a small sling. This method is only a temporary measure for transport to home or hospital.

Forearm.—Sometimes both bones are fractured, often only one—the radius. The latter is known as Colles's fracture, and is nearly as common as that of the clavicle. With it there is usually some impaction; a very similar fracture occurs in motor drivers hit by the springing back of the starting handle. The loss of power, swelling and deformity are obvious. The forearm should be placed on the lower part of the chest with the palm of the hand flat over the tip of the sternum and the thumb pointing upwards (Fig. 191). Two long splints, extending as usual beyond both elbow and wrist, are placed on the inside and the outside of the forearm. They are fixed by a circular bandage above the site of fracture, and by a figure-of-eight round the wrist and hand. Finally the arm is placed in a large arm sling.

Carpus, Metacarpus, Phalanges.—Any of the bones of the hand may become crushed. Take a splint which reaches from well beyond the finger-tips to the middle of the forearm; pad it well, and on it gently lay the forearm and hand, flat and palm downwards. Fix the splint by a figure-of-eight bandage passed round the hand, wrist and forearm, as illustrated in Fig. 192. Then support the whole forearm in a large sling.

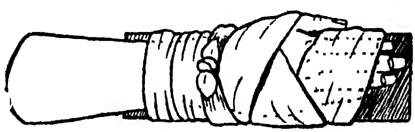


Fig. 192.—Fracture of Bones of the Hand.

Pelvis.—Pain of a piercing character, occurring when the hips are moved, is a sign of fracture of the pelvis, which is not easy to diagnose. The danger to the vital pelvic organs must never be forgotten. Blood in the urine is a bad sign. A broad bandage firmly fixed round the hips helps to give support, but the patient should be well padded as he lies on the ground, while the knees, ankles and legs must be tied together pending the arrival of the ambulance van.

Femur.—The thigh bone is often fractured and this constitutes one of the most difficult and serious injuries of surgery. The Thomas's splint, devised for this condition, should be universally used, and it is fully described later (Section V, Chapter 12), but since these splints are not available in every emergency the old fashioned method must be learned. The common sites of fracture are the neck, the shaft and just above the knee. The first condition occurs often in old people, and the signs are so few that it may be difficult to discover the fracture. The test is the power to raise the heel from the ground when

lying on the back. The toe usually points outwards, and there may be shortening of 2–3 inches. The treatment begins by gripping the foot and ankle of the affected side and gently putting traction on the leg until the two feet are level. Then tie the two feet together. The St. John Ambulance Association recommends the application of seven further bandage which should be placed under the patient as shown in Fig. 193, and numbered

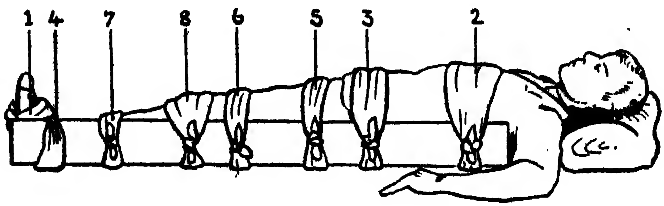


FIG. 193.—FRACTURE OF FEMUR. THE BANDAGES SHOULD BE TIED IN THE ORDER GIVEN BY THE NUMBERS. NOTE THAT THE FRACTURE HAS OCCURRED BETWEEN 5 AND 6.

2–8. A long splint is then obtained. This is best improvised from a floor board or a fence spar, and it must reach well up into the armpit and well beyond the feet; it is placed along the side of the injured thigh and tightly fixed by tying the bandages in the order given in Fig. 193. No. 4 bandage is fixed by a knot in the arch of the boot; the others are knotted on the outside of the splint.

Patella.—As we already know, fracture of the kneecap is commonly the result of muscular action. The immediate action is that the patient falls helplessly to the ground while the pain

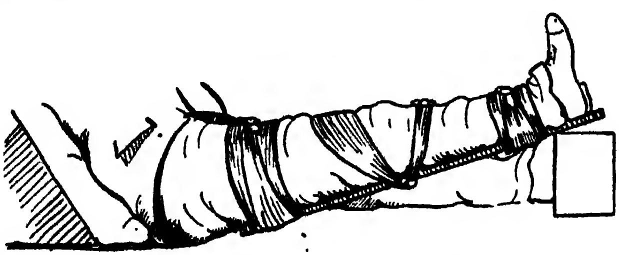


FIG. 194.—FRACTURE OF THE KNEECAP.

and swelling point to the knee as the site of injury. The gap in the bone can be felt. Raising the head and the shoulders of the patient, place a support at his back and shoulders. Gently raise the limb, and attempt to make it straight. Get a long splint,

reaching as far up on the hip as possible and well beyond the heel. Lower the limb gently on this splint, making it an inclined plane by putting a box below the lower end. Tie two bandages, round the thigh and round the ankle, to fix the splint. Take a narrow bandage and put its centre at a point just above the knee joint; carry the ends round the back of the knee and bring them forward to a point below the knee, where they are tied. Cold water dressings or an ice bag may be applied to the knee (Fig. 194).

Leg.—The tibia may be fractured in its shaft, the fibula acting as a splint. But the commonest fracture is Pott's fracture, which involves the tibia and fibula at the lower end, tears the ligaments and may cause serious displacement of the foot outwards and backwards. Many so-called sprains of the ankle are fractures.

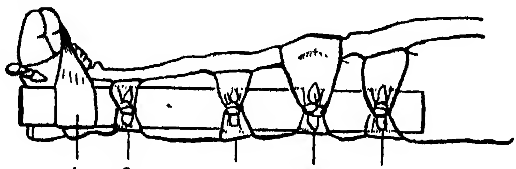


Fig. 195.—Fracture of the Bones of the Leg.

The first thing to do is to steady the ankle and try to get the foot into its natural position. Two splints, extending from above the knee to beyond the foot, should then be applied on either side of the leg. Five bandages should be fixed, Nos. 1 and 2 above and below the fracture respectively, No. 3 just above the knee, No. 4 a figure-of-eight round both feet, No. 5 a broad bandage across both knees. If a splint cannot be got, the two lower extremities should be tied together (Fig. 195).

Foot.—Any part of the foot may be injured by crushing with heavy machinery, falling timber or various other heavy weights. Swelling quickly occurs and often obliterates the evidences of fracture. As quickly as possible, take off the boot. Pad a small splint, which should extend well beyond the toes and the heel, and place it firmly against the sole of the foot. Apply a figure-of-eight bandage, beginning by placing the centre of it over the instep (see Fig. 196). Then put a rolled coat or small cushion below the foot to support it.

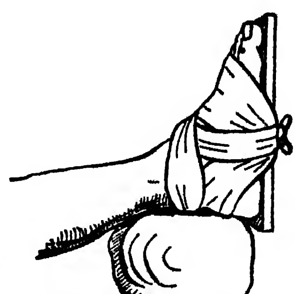


Fig. 196.—Fracture of the Foot.

Sprains

A sprain of a joint means that by wrenching, tearing or twisting, the ligaments and the tendons become damaged in varying degrees. A severe sprain is as serious as a fracture from a treatment point of view, and many sprains look very like fractures at the beginning. On the other hand, many fractures may be mistaken for simple sprains. The x-ray examination puts all doubts at rest. The signs of a sprain are severe pain, often causing sickness, swelling, limited movement and finally discoloration. The best way to deal with a severe sprain is to treat it as a fracture. No one will scoff at the first aider who applies a splint to a sprain, but much criticism will follow the application of a simple bandage to a fracture. The limb should be comfortably supported. Cold water bandages should be applied frequently over the joint to begin with; if these fail to ease the pain, wring out a piece of flannel in hot water to which a little turpentine has been added. A sprained ankle is the commonest type of this accident. Out of doors, it is usually impossible to remove the boot, therefore a bandage should be applied under the instep and then carried several times round the ankle and finally tied tightly. It can be further tightened by adding water. As soon as possible, the boot should be removed.

Dislocations are a bad form of sprain involving the displacement of the bone or bones of a joint. They should be treated as for sprains. Their hospital treatment is fully described in Section IX, Chapter 4.

CHAPTER 4

BURNS, SCALDS AND FROSTBITE

DEFINITIONS. SIGNS. TREATMENT OF BURNS AND SCALDS. SCALDS; BURNS CAUSED BY DRY HEAT, ELECTRICITY, FRICTION. BURNS BY CORROSIVE ACIDS. BURNS BY CORROSIVE ALKALIS. FROSTBITE.

Definitions.—A burn may be caused in 5 different ways. First it may be the result of excess of heat from fire or from red hot metal, i.e. dry heat. Secondly it may be caused by a corrosive acid such as vitriol. Thirdly it may be caused by a corrosive alkali—strong ammonia, quicklime, caustic soda. Fourthly a burn is the injury found in those who have received a strong electric current from a live rail or wire or who have been struck by lightning. Lastly there is the " brush burn," a condition of erosion of the skin caused by the rubbing of a rapidly revolving drum or wheel.

A scald is the result of moist heat. It may be caused by steam, boiling water, hot tar or hot oil.

Signs.—There are various degrees of burns and scalds, but from a first aid point of view it is unnecessary to be able to differentiate them. The skin may be reddened, as when a person sits with thin stockings too near a fire; a large blister or blisters may form, as is common in scalding; or the whole of the tissues of the affected part, fat, fascia, muscle and even bone, may be charred and destroyed. The two chief dangers in burning accidents are sepsis and shock. The latter is due to the nerve injury and may be severe even with an apparently trivial burn; the former is caused by the easy access provided for microbes, especially as the clothes often stick closely to the wound. The subject is fully discussed in Section IX, Chapter 3.

Treatment of Burns and Scalds

1. **Scalds; Burns caused by Dry Heat, Electricity or Friction.**—The first aid treatment of this group varies very little. The first thing to do is to put out the fire. This may affect the child or the room. To approach a burning person, the first aider should hold a rug, blanket, tablecover or sheet,

soaked in water if possible, in front of him. Try to envelop the victim in the cloth, then lay him flat on his back if the flames are on his front, and on his face if the flames are on his back. Fire always burns upwards, therefore by laying the patient flat the face, head and neck are saved, while by allowing the burning area to remain uppermost, the rest of the body will stand less chance of being burned. Make sure that the cover or blanket is kept close to the patient until the burning is completely overcome.

Secondly in the case of children (who are usually burned by a piece of coal which shoots out of the fire into the cradle or are scalded by pulling over the teapot on themselves) a warm bath made by adding a handful of baking soda to two gallons of water at 98·4° F. should be got ready and the child should be put in as he is, no attempt being made to remove the clothes. The pain and the shock will be diminished. It may be possible to take off one or two outside garments whilst the child is in the bath.

Thirdly in ordinary burning or scalding accidents, remove the clothing by cutting round the injured part. Never try to drag burnt cloth from the area. If it comes away easily, well and good. Leave any blisters as they are. They are excellent natural protectives. In order to shut out the irritating and germ laden air from the burn, soak the injured part in a lotion similar to that described above for children's baths. Having procured some dressings, apply to the area lint or gauze squares, soaked in a saturated solution of baking soda, making sure the lint is kept wet. Then pad well with cotton wool, and bandage as lightly as possible. There are many other methods but, for first aid purposes, one method only should be adopted.

Fourthly there is great shock even with the smallest burn. It may be necessary to treat this condition by laying the patient flat, giving him stimulating drinks, such as hot coffee or tea, and applying hot water bottles to his feet if they are not the site of injury. Gentle massage upwards of the limbs is always beneficial, while all excitement should be avoided by dismissing peremptorily odd onlookers and getting rid of panic-stricken persons.

Lastly facial burns require the provision of a special mask cut out of cotton wool or lint and soaked in baking soda solution. Holes are cut for the eyes, the nose and the mouth.

Burns and scalds of the throat.—This condition may be brought about in different ways, but especially by drinking hot tea. In very serious cases in which the larynx and pharyngeal walls may be damaged there is danger of asphyxia and loss of voice. The treatment consists in giving mouthwashes, gargles and drinks of sodium bicarbonate solutions (about 1 teaspoonful to ½ pint of

water). There may be severe shock. The sooner the patient is in the hospital bed the better.

Burns caused by electricity.—Special importance is attached to this emergency, since there are certain sequelae to all electrical injuries. Commonly the cause is (1) direct contact with a live wire or rail or (2) lightning. Apart from the local burns, which may have a peculiar pattern, there is deep shock. The patient may have to be removed from the source of electricity, in which case the first aider should make certain of personal insulation (by standing on rubber surface or other suitable insulator). It is often possible to switch off the current. First aid may take the form of artificial respiration and of shock treatment. Local burns may be dressed as described above.

2. **Burns by Corrosive Acids.**—Baking soda and washing soda are alkalis, and therefore neutralize strong acids; they should be applied as a solution in the strength of two teaspoonfuls to the pint of warm water in the event of burning by acids. If an alkali is not available, plunge the area affected into warm water. Then treat as an ordinary burn in the way described above.

3. **Burns by Corrosive Alkalis.**—Similarly burns by corrosive alkalis require acids to neutralize them. The commonest domestic antidotes of this type are vinegar or lemon juice in an equal part of water. If lime is the cause of the burn, it must be removed before water is applied. The condition is then treated as mentioned above.

Frostbite

Treatment of simple frostbite was in rather an elementary state until World War II occurred. During this period there was much study made of chilling of the feet, immersion foot, trench foot and frostbite of nose, ears, finger-tips and toes occurring in aviators. The result is that there is now an established routine of treatment in all these cases. First aid treatment is always conservative, the main principle being to avoid sudden application of heat above body temperature. Rest, wrapping in cotton wool and protection from injury are the chief essentials. In extensive body chilling, close contact with another human body, primitive though it may sound to be, has been found to be of the greatest service. Again it is a matter of rapid removal to hospital when the case is one just beyond the mildest degree. It should be borne in mind that friction of any kind, even in slight frostbite, is contraindicated.

CHAPTER 5

POISONS

CLASSIFICATION OF POISONS. CORROSIVES. IRRITANTS. NARCOTICS. GENERAL TREATMENT OF POISONS. EMETICS. COMMON INDIVIDUAL POISONS. THE PHENOL GROUP. CORROSIVE SUBLIMATE. IODINE. OPIUM. ALCOHOL. STRYCHNINE. PRUSSIC ACID. STINGS OF WASPS AND BEES. MAD DOG BITES. SNAKE BITES.

THE various chemical properties of poisons are not as important to the first aid student as are the results of their actions. For all practical purposes a poison may be defined as a substance which is so antagonistic and foreign to the human subject that it is capable of rapidly destroying the tissues and of causing even death. Whether taken by accident or as a means of suicide, a poison can act through different channels. It may be a solid, a liquid or a gas. Thus it may be introduced through the mouth or the lungs or by inoculation. It is essential to know the types of poison, how poisons act and how their effects may be quickly neutralized. (Note: Coal gas poisoning is dealt with under Asphyxia on p. 353.)

Classification of Poisons

Although poisons as a whole form a very complex group, including many chemicals used in industry and in the domestic sphere, drugs taken in excess, drugs meant for external use only taken internally, disinfectants drunk as suicidal agents and coal gas inhaled with a similar purpose, we can classify poisons in 3 chief groups. These groups are known as the corrosives, the irritants and the narcotics. It must be remembered also that a poison can act immediately in an acute way or with considerable delay in a chronic way.

Corrosives.—These are substances which destroy by burning the human tissues. Wherever they touch a portion of the flesh they cause ulceration and complete destruction of tissue and generally speaking their effect depends upon the time they are left in contact with it. They are thus easily proved by examination. The difficulty is to know what poison has been at work;

thus there may be a slight delay in selection and administration of the antidote. The symptoms of corrosive poisoning are pain, burnt tracts on the mouth and throat, retching, vomiting of blood sometimes, interference with the breathing, shock and collapse.

The common corrosives are the strong acids and alkalis, including acetic acid, sulphuric acid, nitric acid, hydrochloric acid, oxalic acid, carbolic acid (or phenol) with its allies, liquid ammonia, caustic soda and corrosive sublimate.

Irritants.—Irritants are not so severe on the flesh, but they cause marked irritation of the parts they reach, especially the lining of the alimentary canal and other mucous membranes. The symptoms are usually a burning in the throat and over the epigastrium, while retching, vomiting, diarrhoea and colic complete the picture. There is often collapse after the initial symptoms have passed off; sometimes the collapse occurs at once.

The common irritants are arsenic, lead, phosphorus, zinc, iodine, copper, tartar emetic, cantharides, croton oil; poisonous berries, such as laburnum pods; "mushrooms," mussels, the various food poisons which are toxins of organisms living in putrefying food ("ptomaines," botulines) and foxglove.

Narcotics.—In this group, some members of which have a primary irritant effect, the poisons circulate in the blood, and reaching the brain or nervous system, or both, cause depression resulting in preliminary delirium, convulsions or other active demonstrations and finally coma.

The narcotics are divided into 3 sub-groups each of which has characteristic symptoms.

Group 1.—Sleep is induced at once, and this is gradually deepened until coma and general depression, with anaesthesia, is produced. Examples: Opium (morphine), cocaine, veronal.

Group 2.—There is a preliminary delirium. The symptoms gradually develop into coma. Examples: Alcohol, chloroform, belladonna, ether, camphor, stramonium.

Group 3.—Convulsions are the first symptom. There is collapse between them. The patient is seized with a succession of fits. Examples: Strychnine, prussic acid, aconite.

General Treatment of Poisons

In dealing with poisons, there are two great principles: 1. find the cause; 2. administer the antidote.

Find out if there is evidence of corrosion of the mouth as indicated by stains, and white or bleeding patches on the tongue, mucous membranes or lips. Keep any vomited matter, contents of bottles found near the patient or food which may be suspected. Do not forget that the nose will often discover what the eye does

not see e.g. carbolic acid, lysol, alcohol. Search the patient's clothing for drugs. In coal gas poisoning the cause advertises itself long before the patient is reached.

The treatment is urgent at all times. Send a brief note, clearly written in block letters, to the nearest doctor. If breathing has stopped, artificial respiration must be done at once. If it is certain that there is no question of a corrosive action, give an emetic. If corrosive poisoning is proved, give an alkali in the case of acids and an acid in the case of alkalis. Alkaline remedies for acid poisoning are lime water, or two tablespoonfuls of whitening, magnesia or chalk in a pint of cold water. Acid remedies for alkaline poisoning are vinegar and water half and half or lemon and water of the same strength. The more one can get the patient to take of these remedies the better. When it is not certain what type of corrosive has been taken, try to dilute it as much as possible with tumblerfuls of water. When the destructive element has been neutralized, soothe the pain of the corroded area by making the patient take olive oil, salad oil, liquid paraffin, barley water, flour and water or gruel. These form a protective film over the mucous membrane. In cases in which there is swelling of the throat likely to cause complete closure of the air passages, poultice the neck with hot linseed, or keep on applying flannel wrung out in boiling water. Give sips of cold water or of the gruel or barley water as described above.

When in other types of poisoning the emetic has done its work in removing the irritant, give two tablespoonfuls of castor oil to an adult or two teaspoonfuls to a child; failing that, any of the demulcent drinks described above. The exception is phosphorus poisoning, in which oil is forbidden.

If a narcotic is responsible, strong coffee should be given without milk. Try to keep the patient from dropping off to sleep again by making him walk about, by sponging his face, hands and chest with very cold water or even by slapping him vigorously. If delirium is present, give an emetic; it is difficult to do this when there are convulsions, but it may be accomplished in the quiescent stage. Artificial respiration should be attempted also in the intervals between fits.

The general treatment of shock and collapse must be carried out as already described on pp. 310–311. The white of an egg, milk, raw eggs beaten up with milk, thin flour paste, strong tea and cold water are all very helpful in every case. If there is a specific antidote and it is available, it should be given at once.

Emetics.—The full list of emetics is a long one, but 6 of the best known are given below.

1. Tickling the back of the throat with the index finger or with a feather.

2. Mustard: give a tablespoonful in half a pint of warm water.

3. Common salt: two tablespoonfuls in half a pint of warm water.

(Remember that 2 and 3 may be found on any dinner table.)

4. Smelling salts: the strength is half a teaspoonful in half a pint of warm water.

5. Powdered alum: a tablespoonful in half a pint of tepid water.

6. Tincture of Ipecacuanha B.P. 1932: a dessertspoonful in half a pint of warm water.

These remedies can be repeated if they fail the first time. Do not delay more than 5 minutes in the giving of the second emetic. Provide fluids in abundance.

Common Individual Poisons

The Phenol Group (*Phenol* (*carbolic acid*), *lysol*, *izal*, *cresol* and other such disinfectants).—*Features:* stains and white patches on the mucous membranes; frothing at the mouth; smell of carbolic acid; greenish black urine; collapse. *Antidote:* Epsom salts or Glauber's salts, one tablespoonful in a tumbler of warm water.

Corrosive Sublimate.—*Features:* metallic taste in the mouth; signs of corrosion. *Antidote:* whites of eggs beaten up with milk.

Iodine.—*Features:* great thirst; brown stains on mucous membranes: vomitus blue or yellowish brown. *Antidote:* starch and water.

Opium.—*Features:* drowsiness or heavy sleep; very weak pulse; heavy stertorous breathing; pupils are contracted markedly (the pin-point pupil). *Antidote:* in addition to remedies for narcotic poisoning, give as much potassium permanganate as will cover a sixpenny piece (10 grains), or a tablespoonful of Condy's fluid in half a tumblerful of water.

Alcohol.—As is well known, there are various degrees and manifestations of alcoholic poisoning. In the advanced stage, alcoholic intoxication is a serious condition and the victim should never be treated as a delinquent, but carefully dealt with as a patient. The "stimulation stage" may quickly pass into the stage of coma, which is marked by blueness of the face, stertorous breathing, cold, clammy sweating, lowering of the body temperature and a dilated condition of the pupils, which do not contract under the influence of light and which give to the patient a gaunt, lifeless appearance. The stomach pump is the quickest remedy, but if that is not immediately available in the hands of a physician, give an emetic of mustard and water, then hot strong coffee, and employ all the devices used in the treatment of shock.

Strychnine.—The spasms of the muscles in this condition may make the patient adopt peculiar attitudes, such as an arched condition of the back (opisthotonos). Convulsions occur frequently, causing a condition of choking, with purple complexion. When the fit passes off for a few moments the patient is very collapsed. The treatment is very difficult, as emetics are not easy to pass into the stomach and artificial respiration, which is sometimes recommended, can be done only between the spasms. Strong tea is good, also a little liquor of iodine in water. Crushed animal charcoal mixed with large quantities of water has also been recommended. In this type of poisoning, consciousness and all the senses are retained, adding to the difficulties of the treatment.

Prussic Acid.—This is probably the speediest type of poison known. Frequently there is a piercing scream, a convulsive stretch and death. In less severe cases, respiration is very embarrassed and collapse follows. The scent of bitter almonds, with which hydrocyanic (prussic) acid is associated, is often the clue to the cause. The treatment consists of a dose of *sal volatile* or brandy in equal parts of water and the application of cold water; when circumstances permit plunge the patient into a cold bath. Artificial respiration must be kept up for a long time.

Stings of Wasps and Bees.—These minor cases can be treated by applying plenty of ammonia and water, baking soda or the domestic blue bag. The old wives invariably advise the juice of a raw onion. The sting can be removed by pressing a hollow ring e.g. a watch key over the affected area.

Mad Dog Bites.—The wound should be cauterized immediately, especially if there has been free bleeding. A tourniquet should be tied above the bite to keep the poison from spreading via the veins. Phenol, carefully applied, is the best caustic.

Snake Bites.—Give two tablespoonfuls of brandy in water. See that the wound bleeds freely. Put on a tourniquet as above. Instead of the caustic, use permanganate of potash well rubbed into little scarifications made round the bite with a pin or sharp-pointed penknife. Then take off the tourniquet so that the permanganate may circulate in the blood.

CHAPTER 6

LOSS OF CONSCIOUSNESS AND CONVULSIONS

LOSS OF CONSCIOUSNESS. CAUSES. EXAMINATION OF THE PATIENT. TREATMENT. SPECIAL STATES OF UNCONSCIOUSNESS. FRACTURE OF THE SKULL. CONCUSSION. COMPRESSION. SHOCK AND COLLAPSE. FAINTING. APOPLEXY. SUNSTROKE AND HEAT STROKE. CONVULSIONS. EPILEPSY. HYSTERIA. CONVULSIONS OF CHILDREN.

FROM our studies in physiology, we know that the brain and the spinal cord and nerves are the chief directing agents of the body. When any serious injury occurs in the nervous system, the control of the body is therefore lost and we find that there is interference with the normal sensory and motor functions. This may be demonstrated as paralysis or by abnormal movements. Of the latter, convulsions or fits are the main feature. Coma, or loss of consciousness, the outcome of paralysis of the brain centres, is the result of serious disintegration of the sensitive tracts of the brain. It is a very complicated process, produced by various conditions. Severe physical injury of some part of the body, overdoses of drugs, strong mental impressions and disease or interference with the structures intimately associated with the brain itself may cause the state of shock, which has graduated degrees of intensity, resulting in a type of reaction varying from slight excitement and irritability to profound coma.

Loss of Consciousness

Sleep is natural insensibility which overcomes us when we are either physically or mentally tired, or both. It is a natural physiological provision to allow recuperation of the fatigued brain cells. Abnormal insensibility may be slightly shown, as in stupor (e.g. when we get a slight knock on the head) or absolute, as in coma, a very deep stage of unconsciousness, characterized by complete insensibility from which it is impossible to rouse the patient without the use of some drastic remedy. In stupor, the patient can be shaken or wakened up momentarily to consciousness; his pupils react to light and the eyelids wink when the

cornea is touched. None of these reactions is effective in the comatose person. He is completely under the influence of some gravely depressing force which makes him appear lifeless and inert.

Causes.—When a person is found lying in the roadway or on the floor of a room, in a state of coma, the following list of probable causes must be gone through in the mind of the first aider.

A. Alcohol.
   Apoplexy.
E. Epilepsy.
   Emotion: (causing shock, fainting or prostration).
I. Injury: (fractured skull, concussion, compression, sun-stroke, heat stroke).
   Intoxication: by various poisons.
O. Opium and other narcotics.
U. Uraemia (in chronic kidney affections).

Examination of the Patient.—The first thing to be ascertained is the degree of insensibility. If the patient can be roused even for a few seconds he may be able to mutter his name, therefore he should be given the chance of doing so; facts, however, stated by people in the mildest state of confusion can never be regarded as accurate or authentic. Therefore, for practical purposes, the first aid student must use his common sense and make up his mind from the evidence presented to him.

1. *Pulse.*—If the pulse cannot be felt at the wrist, do not conclude that death has taken place. Try the temporal artery or the carotid artery or even the apex beat of the heart. Sometimes the pulse is weak and slow (" thready "), sometimes fast, sometimes irregular. Observe it for a minute or two.

2. *Breathing.*—Count the respirations, noting whether they are greater than, or less than, 15–18 per minute. Does the patient take the full inspiration, or is the breathing shallow? Is there stertor (strong snoring, with puffing of the cheeks and blowing of the lips)? The smell of the breath is important from the point of view of phenol poisoning, but it has been clearly established that alcohol in the breath does not indicate the cause of unconsciousness, since there is a habit among people of taking spirits in small doses as a stimulant, and in any case, one teaspoonful of whisky may cause quite as much of a " breath " as half a pint. Alcoholic poisoning has been fully discussed in the previous chapter.

3. *Head injuries.*—The skull must be examined for contusions or deeper injuries; look especially at the temples, vertex and occipital region. See if there is bleeding from the ears, nose or mouth or signs of bloodshot eyes. There may be frothing at the

mouth in epilepsy, foreign bodies in asphyxia and burns in corrosive poisoning.

4. *Body injuries.*—Make a rapid survey of the rest of the body for gross injury or paralysis.

5. *Temperature.*—Is the temperature subnormal? Ascertain this by putting the back of the hand on the skin of the patient's chest or of the upper part of his abdomen.

6. *Pupils.*—Open the eyelids, and find out how the pupils react to the strong light of a match, the direct sun or an electric torch. Are they minute, widely dilated, fixed, sluggish or unequal?

Treatment.—We have already mentioned shock due to haemorrhage, and its treatment (pp. 313–314), and since it is an example of stupor or of coma, many of the principles enumerated are those of the treatment of insensible states in general; they need only be dealt with summarily at this point.

The necessity for laying the patient on his back, undoing all tight clothing, raising the head or the feet according to the presence of plethora or pallor, permitting plenty of fresh air, stopping bleeding if present, sending for a doctor, keeping the heat up by rugs, blankets and hot water bottles, dealing with any special condition, and treating any injury has been fully appreciated. In addition to the above, it is well to remember that it is dangerous to give food or remedies to an insensible person, even although these may be in fluid form, but when the patient "comes round," he can have sips of water, hot tea or coffee, unless haemorrhage is active. If a narcotic has been taken, try to prevent sleep, but in all other cases encourage it. Never leave the patient alone. If there are one or two helping, each can take a turn of special duty as attendant.

Special States of Unconsciousness

Fracture of the Skull.—The special points to be noted in this condition, apart from those dealt with under Fractures (pp. 313–314), are the preliminary excitement lapsing into coma. In addition to bleeding from the ears or nose (common in basal fractures), there is a slow pulse, stertorous breathing and unequal pupils.

Concussion.—When the skull is fractured there is always concussion of the brain, but the brain may be affected with concussion apart from this injury. An ordinary stun (e.g. when a person slips on the ice and knocks the back of the head on the hard surface) is a form of concussion. Concussion is characterized by stupor, with pallor, small quick pulse and shallow breathing. Coma may develop.

Compression.—Frequently concussion leads to compression owing to the liberation of blood or other fluids inside the cranium, while a severe depressed fracture of the skull may also compress the brain. The evidences are typical of the condition. There may be a history of a severe head knock, with concussion which passed off in 24 hours. A few days later, however, all the symptoms of compression of the brain appear. This is due to the fact that in the interval a slow leakage or collection of fluid has gathered. The consciousness is lost gradually. There is flushing of the face and sometimes rise of temperature. The power and senses may not be entirely lost, in fact the patient gives the impression that his brain is "muffled," which indeed it is. As the unconsciousness deepens, stertor and unequal pupils are evident. It is a serious condition. In addition to the application of the general treatment already described, sponge the head and neck with very cold water or apply an ice bag. In all cases of concussion, however slight, the patient should be told to keep in touch with his doctor for at least a fortnight afterwards.

Shock and Collapse.—The word, shock, is used in various ways. Popularly it usually is held to indicate the condition of apoplexy, but in Medicine it means a depressed condition of the whole system, occurring after serious injury, severe haemorrhage, burns or a big operation. It is the reaction of the brain to a sudden great strain put on it. It may be followed by collapse or death. Collapse is more negative than shock. The latter condition may be one of stupor, with intervals of very clear consciousness, during which the patient may deceive the onlooker by being free from pain, calm and collected. In collapse, the face is pale and clammy, with an ashen grey complexion; the pulse is almost imperceptible; the breathing very shallow; and the temperature is below normal. The treatment has already been described (pp. 310–311 and 313–314).

Fainting.—Emotional stress, sudden good or bad news, excitement, fright, starvation, effects of a hot, stuffy atmosphere or too strong imagination may all produce the state of syncope which we call a fainting fit. It is common in young nurses and students at their first operation or seeing serious casualties for the first time, but it is nothing to worry about, being more alarming than serious. The cause is a sudden stoppage of the heart's action, due no doubt to severe strain on the brain centres. The patient may have preliminary slight sickness or a sensation of "gone-ness"; then black specks appear before his eyes and he falls down in a stupor from which he soon recovers. The pallor, clammy sweating, thin pulse and shallow breathing are typical. The remedy is to keep the head low and to dash cold water in the face. Allow plenty of fresh air and freedom of the clothing.

A hot water bag may be put on the pit of the stomach. Massage of the limbs upwards is helpful in bringing the patient round. Smelling salts also restore his equilibrium. A glass of water taken slowly after the fainting fit has passed off is very much appreciated.

Apoplexy.—In various guises, this form of unconsciousness is known as "a shock," "a clot of blood on the brain" and a "stroke of paralysis." It is the sequel to rupture of the branch of the middle cerebral artery which runs in the internal capsule of the brain; this condition produces dangerous pressure on the vital motor fibres. It is also an accident associated with elderly people in whom has developed a brittle condition of the arteries owing to high blood pressure. There is usually great flushing of the face, the pulse is slow and bounding and the temperature is slightly raised, while the breathing is markedly stertorous, with a great deal of puffing of the cheeks. The last sign is accentuated by the fact that owing to the localized nature of the haemorrhage, one side of the body only is paralysed, the condition of hemiplegia. This makes the cheeks flaccid on one side, while the arm and leg of the same side are completely paralysed. When the patient recovers, speech is slurred and difficult. Immediately after the paralysis has occurred we notice that the pupils are unequal. The affected limbs fall down lifelessly when we lift them and let go. The treatment is much the same as for other similar states. In applying hot water bottles or other forms of heat—such as a blanket or hot bricks protected with old flannel—to the limbs and abdomen, first aiders must remember that the patient is insensible to heat therefore great care must be taken not to cause a burn. If possible, raise the head slightly and let it lie on an ice bag. Never give alcohol.

Sunstroke and Heat Stroke.—These may come on either in the middle of intense heat, or at night as a result of exposure to strong direct sun rays during the day. The main points are the great heat of the skin, which is very dry, rise of temperature sometimes to 107° F. and collapse. The upper part of the spinal cord is affected as well as the brain, therefore in addition to the general treatment, take measures to reduce the excess of body heat by putting the patient in a very cool place, removing his clothing, fanning him vigorously or rolling him in a sheet containing crushed ice. The head and neck should afterwards be covered with cold water cloths or supported by an ice bag.

Convulsions

When there is activity of all the muscles of the body or of a group of muscles, demonstrated in an uncontrolled way and

entirely without the influence of a person's will, a state of convulsions exists. These may be constant, intermittent, of fine tremor or of coarse tremor depending on the cause. The chief causes are epilepsy, hysteria, convulsive states in children and the action of certain poisons we have already studied e.g. strychnine, prussic acid, certain fungi and one or two types of poisonous berry.

Epilepsy.—This is usually a lifelong complaint, but those most frequently discovered in the street in a typical epileptic fit are young adults. It should be remembered that the layman usually thinks of this occurrence as " a stroke." The signs are typical. First there is the " aura," which is the short warning to the patient, who immediately gives a yell and falls down into a state of unconsciousness, during which he has a spasm of the muscles, with purple-black face, frothing mouth and twitching eyes. The breathing is groaning in type. During the spasm of the jaws, the tongue is frequently bitten. The arms and legs go into wild convulsions and the patient may damage himself and the onlookers. After a short period of consciousness with acute mental distress, he relapses into a depressed state, which may last for some hours and which is frequently characterized by automatism, during which the patient may be dangerous and, in effect, a criminal lunatic. To deal with this disease, first put a cork or a small piece of wood wrapped in a handkerchief between the teeth to prevent biting of the tongue. Then remove the patient away from a fire or machinery. Control but do not suppress his convulsions, so that they are completed without damage to the patient or to the people around him. After he is conscious, see that he goes home accompanied by a friend.

Hysteria.—This condition can be dismissed in a few words, as it is not a serious matter. It is purely a state in which the individual has allowed the nerves to get the better of him. We might say more accurately that young and impressionable females are usually the sufferers. There is no organic basis for the fits, which are, in many ways, demonstrations of petulance and selfishness. The whole nervous system is thrown into a state of excitement and the " fits " are theatrical in character. All the emotions are allowed to get completely out of control. Unlike epileptic subjects, the hysterical person chooses the time and the place for her outburst, making sure she has an audience and generally throwing herself on a soft carpet or a well sprung settee. There she performs various demonstrative evolutions, such as biting her hands, howling at the top of her voice, alternately laughing and crying and generally making a complete fool of herself. The only thing to bring such people to their senses is to give them a good talking to and to rouse them with a

cold sponge applied not too gently to the face. More homely remedies are unofficial, but successful from the capable hands of a sensible mother, whatever the age of the patient. Often, however, a good scolding is enough and while sympathy and understanding should be the rule, any coddling is sure to be taken advantage of. Hysterical people may adopt all sorts of devices e.g. self-mutilation, or sucking a piece of soap in order to imitate epilepsy and other states. There is never unconsciousness.

Convulsions of Children.—In children between the ages of 1 and 5, convulsions may occur apart from the well known organic diseases in which fits are the rule. Undoubtedly dietetic defects are at the root of the common fits of early years, especially when weaning, teething, chronic constipation, severe pain or injury are active. Threadworms often lead to fits. The removal of the cause soon stops the tendency to these attacks. The signs are sudden spasm with blackening of the face, then stertorous breathing, twitching of all the muscles, frothing at the mouth and squinting of the eyes. When the fit is past, the child is very pale, weak and obviously tired. Unconsciousness lasts only a few minutes. The remedy is the placing of the child in a warm bath at about 100° F., which reaches up as far as the level of the child's nipples. Add a teaspoonful of mustard powder to the bath. While the child is in the bath, sprinkle cold water on his head or keep the cold sponge constantly applied. Then remove the child, wrap him up well and keep him quiet for the rest of the day. The doctor will see that the bowels are well purged.

CHAPTER 7

ASPHYXIA

CAUSES. DROWNING. CHOKING. GAS POISONING. ARTIFICIAL RESPIRATION. SYLVESTER'S METHOD. MODIFIED SCHÄFER METHOD. LABORDE METHOD. CRADLING METHOD.

ANYTHING which obstructs the entrance of oxygen and the exit of carbonic acid gas causes the condition of asphyxia, which is equivalent to a form of poisoning and which is often accompanied by unconsciousness.

Causes.—The causes of asphyxia can be tabulated as follows.

1. *Closing of the main air passages.*—This may be done by pressure inside the passages (drowning, by a diphtheritic membrane, choking over a piece of meat or other such obstruction), or by pressure outside the passages (strangulation, hanging, smothering, swelling of the loose tissues round the throat in disease, abscess or the sting of an insect).

2. *Breathing poisonous gas.*—The best example of this is coal gas, but the poison gases of warfare, the fumes from coke, charcoal or anthracite stoves, ordinary coal smoke, the exhaust of a motor car, the gas from sewers and certain gases in mines are possible asphyxiants.

3. *Crushing of the chest.*—This is a very common occurrence at the seaside in summer. Children dig large sandpits which suddenly collapse and bury them. The pressure of the crowd at big football matches is also a danger to breathing as the spectators are so close that they may prevent the natural rise and fall of the thorax.

4. *Nervous affections.*—Most of these have already been dealt with. An electric shock, a stroke of lightning or the effect of certain narcotics may end in asphyxia.

In this chapter 3 typical forms of asphyxia are described and the general treatment outlined. These are drowning, choking and gas poisoning.

Drowning.—Prompt action is necessary. The patient appears to be dead owing to waterlogging of the lungs and exhaustion of physical effort. The skin is clammy and pale.

There may be no movement of the thoracic muscles; the pulse may be absent at the wrist.

Treatment.—However bad the patient may appear to be, do not give up hope. All the authorities agree that no time should be wasted; put the patient immediately in the position for artificial respiration, and begin at once to apply the movements. A bystander should be sent to fetch a doctor. Keep up artificial respiration for hours, working in relays if necessary. Be ready to resume artificial respiration if there should be any second failure after you have established breathing the first time. If the patient's wet clothing can be removed, and dry blankets provided, he should be wrapped up in them, and shock treated in the usual way while he is getting artificial respiration. After recovery is assured, give him sips of hot tea or hot coffee or strong beef tea and get him to bed as quickly as possible.

Choking.—A mechanical closure of the trachea by the lodging of a piece of meat or other foreign body over the opening of the larynx causes rapid asphyxia and death may occur if the obstruction is not quickly displaced, therefore the old fashioned method of thumping the back between the shoulder blades should be adopted, and in young children the best way is often to turn the child upside down. If neither of these methods is successful, open the mouth and pass the index and middle fingers back at the side of the tongue and try to scoop out the lump; it may be possible to force it into the gullet. On certain occasions, a button hook, the blunt end of a spoon or fork or bone eggspoon has proved useful.

Gas Poisoning.—Many gases may cause asphyxiation, as mentioned above. Nearly all gas poisoning is due either to coal gas or to carbon monoxide, both of which are intimately connected with the heating of our houses. Coal gas is universal, and may be poisonous when it is burned and when it is in its non-consumed state. Many suicides are attempted by the simple expedient of putting the head in the gas oven, therefore the first aider may expect to deal with coal gas poisoning more than any other type. In approaching a room full of gas, make sure to tie a wet towel or handkerchief over the mouth, then turn off the gas, open all the windows and try to get the patient into another room. Do not strike a match. The treatment is artificial respiration, but it must be remembered that all coal gas poisoning has a delayed effect and patients should be kept in bed for at least a fortnight afterwards.

Artificial Respiration

There are various methods of performing artificial respiration, which is simply a way of imitating the natural process of breath-

ing when it has ceased from one of the above mentioned causes. There are several methods in use: Silvester's, Schäfer's, Howard's, Marshall Hall's, Laborde's, the modified Schäfer Method recommended by the St. John Ambulance Association and various methods requiring apparatus.

Silvester's Method.—This has the advantage that it can be carried out by one person if necessary. The patient is laid on his back, with a rolled coat placed between the shoulder blades. The operator kneels behind the patient's head, takes one of the wrists in each hand, and pulling the arms right above the patient's head, pauses for two seconds. By doing this he allows the air to fill the lungs. The second movement takes about two seconds to carry out also. The arms are brought down to the sides again, while the forearms are pressed over the lower part

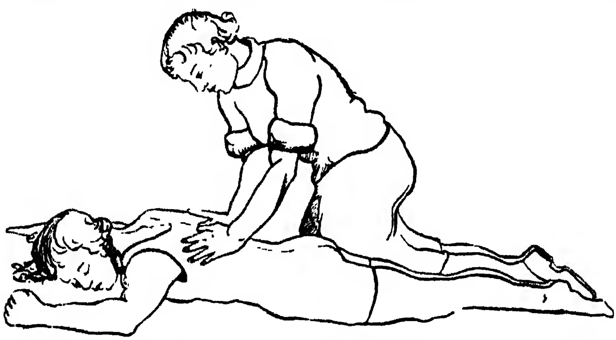


FIG. 197.—ARTIFICIAL RESPIRATION (MODIFIED SCHÄFER METHOD) PART 1.

of the thorax, so that a " grunt " is produced indicating that the air has been forced out. By going through this process about 12 times a minute, the normal movements of breathing can be imitated. It is better when the arms are gripped above the elbows, but a woman operator usually prefers to clasp the wrists as this gives a firmer hold. In drawing the arms up from the chest, a rotatory movement should be performed as this helps to employ the muscles which expand the chest. It is better to employ an assistant to press firmly over the lower part of the thorax when the arms are brought slowly down to the sides.

Modified Schäfer Method.—In this system, the patient is laid on his front, with the head turned towards one side. It is not necessary to pull out the tongue. The arms are pulled out well above the head and kept there. No padding is required and the clothes can remain on until a more suitable opportunity is presented of removing them. The operator kneels at one side

of the patient, looking towards the head. His hands are placed one on either side of the vertebral column, the fingers pointing upwards and spread out in fan shape over the lower ribs. The radial borders of the thumbs should be kept parallel. The arms should be kept very rigid, with the elbows fully extended. By leaning the body weight evenly and firmly on the lower part of the patient's chest, the air is driven out, and the lungs are emptied. Inspiration is produced by relaxing the pressure; this

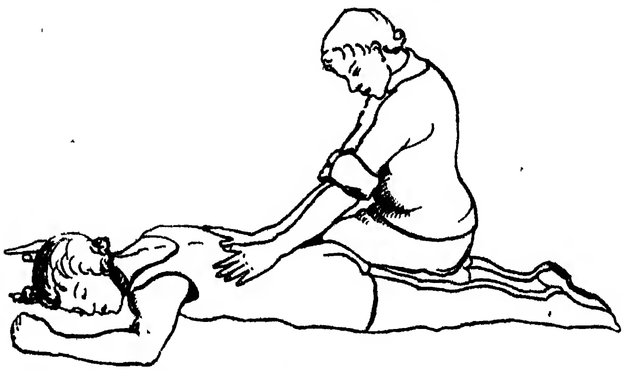


FIG. 198.—ARTIFICIAL RESPIRATION (MODIFIED SCHÄFER METHOD) PART 2.

is accomplished simply by taking away the weight of the body temporarily, but the hands need not be moved. By carrying out this procedure 12 to 15 times a minute, with a regular swaying of the body, a system of breathing can be set up which may stimulate the respiratory centre to action Once this is in action, the artificial movements can be gradually lessened (Figs. 197 and 198).

Laborde Method.—This is a method often adopted when there is injury to both the arms and ribs; further it has been proved to be very useful in cases of asphyxia in children caused by any of the irrespirable gases (e.g. ammonia) and in cases of shock from electricity. The patient is laid flat on his back, the chin is depressed, the tongue is held between the folds of a handkerchief in order to prevent it slipping back. Then the tongue is jerked forwards and allowed to go back, with the operator still retaining control of the tip. These two movements should be repeated alternately at the rate of 15 to the minute.

Cradling Method.—The cradling method of artificial respiration has been found to be invaluable in drowning accidents. It is quite a simple procedure, one person being able to manipulate the cradle when it has been constructed. A door or wide

plank of wood could be used, placed over a strong wooden box or log. The patient should be firmly secured by binding the legs and shoulders to the door thus preventing him from slipping when the gentle tilting movement, a "see-saw" action, is performed. This method is easy; it does not exert the patient, and minimises the risk of injuring internal organs by pressure. The pressure of the abdominal organs or the diaphragm causes the fluid and air to be squeezed out of the lungs. By the next movement, when the limbs are tilted downwards, the pressure on the lungs is released, therefore allowing expansion, when air is sucked in.